IOWA DEPARTMENT OF
NATURAL RESOURCES

2018 Iowa Statewide Greenhouse Gas Emissions Inventory Report

Technical Support Document

Required by Iowa Code 455B.104

December 31, 2019

Iowa Department of Natural Resources
502 E. 9th Street
Des Moines, IA 50319

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Acronyms and Key Terms

AEO	Annual Energy Outlook
AR4	Fourth Assessment Report
BOD	biochemical oxygen demand
BOF	basic oxygen furnace
Btu	British thermal unit
CAMD	Clean Air Markets Division
CEMS	continuous emission monitoring system
CH_4	methane
CO_2	carbon dioxide
COMET	Carbon Management and Evaluation Online Tool
CRP	Conservation Reserve Program
DATIM	Design and Analysis Toolkit for Inventory and Monitoring
DNR	Iowa Department of Natural Resources
DOT	United States Department of Transportation
EAF	electric arc furnace
EIA	United States Energy Information Administration
EIIP	Emission Inventory Improvement Program
EPA	United States Environmental Protection Agency
FIDO	Forest Inventory Data Online
FHWA	Federal Highway Administration
GHG	greenhouse gas
GHGRP	Greenhouse Gas Reporting Program
GWP	global warming potential
HDGV	heavy duty gas vehicle
HDDV	heavy duty diesel vehicle
IDALS	Iowa Department of Agriculture and Land Stewardship
IDOT	Iowa Department of Transportation
IEA	International Energy Agency
IEDA	Iowa Economic Development Authority
ILPA	Iowa Limestone Producers Association
IPCC	Intergovernmental Panel on Climate Change
LDC	local distribution company
LDDT	light duty diesel truck
LDDV	light duty diesel vehicle
LDGT	light duty gasoline truck
LDGV	light duty gasoline vehicle
LULUCF	land use, land use change, and forestry
MC	motorcycle
MMtC	million metric tons carbon
$MMtCO_2e$	million metric tons carbon dioxide equivalent
MISO	Midcontinent Independent System Operator
MSW	municipal solid waste

Acronyms and Key Terms (Continued)

N	nitrogen
NAICS	North American Industry Classification System
NEMS	National Energy Modeling System
NO_3-	nitrates
NO_2-	nitrites
NO_x	nitrogen oxides
N_2O	nitrous oxide
NRCS	Natural Resources and Conservation Service
ODS	ozone depleting substance
OECD	Organization for Economic Co-operation and Development
PET	polyethylene terephthalate
PHMSA	Pipeline and Hazardous Materials Safety Administration
PS	polystyrene
PVC	polyvinyl chloride
RCI	residential, commercial, and industrial
SEDS	EIA's State Energy Data System
SF_6	sulfur hexafluoride
SIT	State Inventory Tool
T & D	transmission and distribution
TSD	technical support document
USDA	United States Department of Agriculture
USFS	United States Forest Service
USGS	United States Geological Survey
VMT	vehicle miles traveled
WRI	World Resources Institute

Chapter 1 – General Calculation Method

Iowa Code 455B.104 requires that "by December 31 of each year, the department shall submit a report to the governor and the general assembly regarding the greenhouse gas (GHG) emissions in the state during the previous calendar year and forecasting trends in such emissions…." This Technical Support Document (TSD) provides documentation and additional calculations to support the *2018 Iowa Statewide Greenhouse Gas Emissions Inventory Report*. Total Iowa GHG emissions from 2009 – 2018 are provided in Appendices A and B of this document. A state-specific inventory provides an in-depth analysis of emission trends and develops a baseline to track progress in reducing emissions.

This inventory is based on statewide activity data from agriculture, fossil fuel combustion, industrial processes, natural gas transmission and distribution, transportation, solid waste, and wastewater treatment. It also includes carbon emitted or sequestered from land use, land use change, and forestry (LULUCF).

Method

Emissions were calculated using the most recent version of the United States Environmental Protection Agency's (EPA) State Greenhouse Gas Inventory Tool (SIT)[1] and using available Iowa-specific activity data. The energy and industrial processes sectors were also supplemented with GHG emissions data submitted by individual Iowa facilities to the federal GHG reporting program (40 CFR 98).

The calculation methods in the SIT are based on the August 2004 version of EPA's Emission Inventory Improvement Program (EIIP) guidance for greenhouse gases (ICF 2004). The individual modules for each sector are Excel workbooks populated with emission factors and default activity data for years 1990 – 2016, but allow the user to enter better state-specific activity data when it is available. Detailed information on the activity data used is provided in the corresponding chapter for each sector, under the "Method" heading. The individual modules then auto-calculate the resulting GHG emissions from each sector. The results from each module were then tabulated in an Excel spreadsheet. The SIT Projection Tool was then used to forecast emissions to 2030. The SIT modules and their corresponding chapters in this TSD are listed in Table 1. The coal module was not used, as there are no coal mines currently operating in Iowa.

Table 1: TSD Chapters and Corresponding SIT Modules

TSD Chapter	SIT Module	Release Date	Pollutants Addressed
Agriculture	Ag	11/05/18	CH_4, N_2O
Energy	CO_2FFC	11/05/18	CO_2
	Stationary Combustion	11/05/18	CH_4, N_2O
Industrial Processes	IP	11/05/18	CO_2, N_2O, HFC, PFC, SF_6
Natural Gas Transmission & Distribution	Natural Gas and Oil	11/05/18	CH_4
Transportation	Mobile Combustion	12/11/18	CO_2, CH_4, N_2O
Waste	Solid Waste	11/05/18	CO_2, CH_4
	Wastewater	11/05/18	CH_4, N_2O
Land Use, Land Use Change, and Forestry	LULUCF	11/05/18	CO_2, N_2O
Indirect Emissions from Electricity Consumption	Electricity Consumption	11/05/18	CO_2
Future Emissions	Projection Tool	10/15/19	CO_2, CH_4, N_2O, HFC, PFC, SF_6

[1] The SIT may be requested at https://www.epa.gov/statelocalenergy/state-inventory-and-projection-tool.

Global Warming Potentials (GWP)

The potency of various greenhouse gases can vary, so greenhouse gas emissions are typically converted to a unit of measure called carbon dioxide equivalent (CO_2e) that allows for better comparison of the impact of different greenhouse gases. CO_2e is calculated by multiplying the mass amount of each greenhouse gas by its global warming potential (GWP) and then summing the resulting values. CO_2e was calculated using Equation 1.

Equation 1:

$$tons\ CO_2e = \sum_{i=0}^{n} GHG_i\ x\ GWP_i$$

Where:

GHG_i = Mass emissions of each greenhouse gas

GWP_i = Global warming potential for each greenhouse gas

n = the number of greenhouse gases emitted

The DNR used the GWPs from the Intergovernmental Panel on Climate Change's (IPCC) Fourth Assessment Report (AR4) (IPCC 2007). The values used are shown in Table 2.

Table 2: Global Warming Potentials

Pollutant	GWP used by DNR (IPCC AR4 2007)
Carbon Dioxide (CO_2)	1
Methane (CH_4)	25
Nitrous Oxide (N_2O)	298
Sulfur Hexafluoride (SF_6)	22,600
Hydrofluorocarbons (HFC)	Vary by pollutant – For a complete list, refer to DNR's Greenhouse Gas Emissions Estimation Guidance.
Perfluorocarbons (PFC)	

Chapter 2 - Agriculture

This chapter includes non-energy greenhouse gas (GHG) emissions from livestock and crop production in Iowa. GHG emissions from fossil fuel-fired agricultural equipment are discussed in *Chapter 6 – Transportation*, and carbon emissions and sinks from agriculture are discussed in *Chapter 9 – Land Use, Land Use Change, and Forestry (LULUCF)* of this document.

GHG emissions are emitted from four agricultural sectors in Iowa – enteric fermentation, manure management, agricultural soils, and agricultural burning. The GHGs emitted are methane (CH_4) and nitrous oxide (N_2O). Table 3 summarizes the source of GHG emissions in each sector. N_2O emissions from rice cultivation were not included, as rice is not grown in Iowa (USDA 2019b).

Table 3: Sources of Agricultural GHG Emissions in Iowa

<table>
<tr><th colspan="2">Sector</th><th>GHGs Emitted</th><th>Source of Emissions</th></tr>
<tr><td colspan="2">Enteric Fermentation</td><td>CH_4</td><td>Microbial activity in the digestive systems of dairy cattle, beef cattle, sheep, goats, swine, and horses.</td></tr>
<tr><td colspan="2">Manure Management</td><td>CH_4, N_2O</td><td>Decomposition of manure during storage and treatment of livestock manure.</td></tr>
<tr><td rowspan="3">Agricultural Soils</td><td>Residues, legumes, and histosols</td><td>N_2O</td><td>Biological nitrogen fixation by crops, crop residues remaining on fields, and cultivation of high organic content soils (histosols).</td></tr>
<tr><td>Fertilizers</td><td>N_2O</td><td>Application of manure, fertilizers, etc. to soils and leaching/runoff of nitrogen into ground or surface water.</td></tr>
<tr><td>Animals</td><td>N_2O</td><td>Animal excretions directly on to soils such as pastures.</td></tr>
<tr><td colspan="2">Agricultural Burning</td><td>CH_4, N_2O</td><td>Burning of crop residues.</td></tr>
</table>

<u>Method</u>

GHG emissions from agriculture were calculated using the United States Environmental Protection Agency's (EPA) State Greenhouse Gas Inventory Tool (SIT) agriculture module dated November 5, 2018 (ICF 2018a and 2018b).

Enteric Fermentation

The SIT calculates CH_4 emissions from enteric fermentation by multiplying various livestock populations by an annual CH_4 emission factor (kilograms CH_4 per head). The data sources for the animal populations used are listed in Table 4. The number of "Feedlot Heifers" and "Feedlot Steers" was derived by applying a 35/65 heifer/steer ratio to the "Total Number on Feed."

Manure Management

This sector includes CH_4 and N_2O emissions from manure when it is being stored and treated in a manure management system. In general, CH_4 emissions increase in more anaerobic (lacking oxygen) conditions while N_2O emissions increase under aerobic conditions (Strait et al. 2008). The same dairy cattle, beef cattle, sheep, goat, horse, and swine populations were used as for the enteric fermentation sector for consistency. Several other animal types were added as shown in Table 4.

Table 4: Animal Population Data Sources

Animal Type	Year	Data Source
Dairy cattle	2018	2018 Iowa Agricultural Statistics Bulletin (USDA 2018a)
Beef cattle		
Sheep		
Breeding swine		
Market swine under 60 lbs.[2]		
Market swine 60 – 119 lbs.[3]		
Market swine 120 – 179 lbs.		
Market swine over 180 lbs.		
Goats	2017 census value used as proxy for 2018	USDA-NASS Quick Stats (USDA 2019b)
Horses		
Chickens		
Hens		
Broilers		
Pullets		
Turkeys		

In addition, the number of "Sheep on Feed" and "Sheep off Feed" were derived by applying a 6.5/93.5 on feed/off feed ratio to the total number of sheep.

Agricultural Soils

N_2O emissions in the agricultural soils sector occur from many different pathways as shown in Figure 1 (EPA 2016). N_2O is emitted when the natural processes of denitrification and nitrification interact with agricultural practices that add or release nitrogen (N) in the soil profile. Denitrification is the process of converting nitrate to nitrogen gas. It is carried out by microorganisms in an oxygen-lacking environment. Nitrification occurs when ammonia is converted to nitrites and nitrates by naturally occurring, specialized bacteria in the environment.

Direct N_2O emissions occur at the site of application of both synthetic and organic fertilizers to the soil, production of N-fixing crops, and integration of crop residues into the soil by practices such as cultivation. Indirect emissions occur when N is made available or is transported to another location following volatilization, leaching or runoff, and is then converted to N_2O (EPA 2016).

Plant Residues and Legumes

Crop production data for alfalfa, corn for grain, oats, rye, soybeans, and wheat (USDA 2019b) were used to calculate N_2O from nitrogen-fixing crops, including alfalfa, soybeans, and rye. It was also used to calculate the quantity of nitrogen returned to soils during the production of corn for grain, wheat, oats, and soybeans.

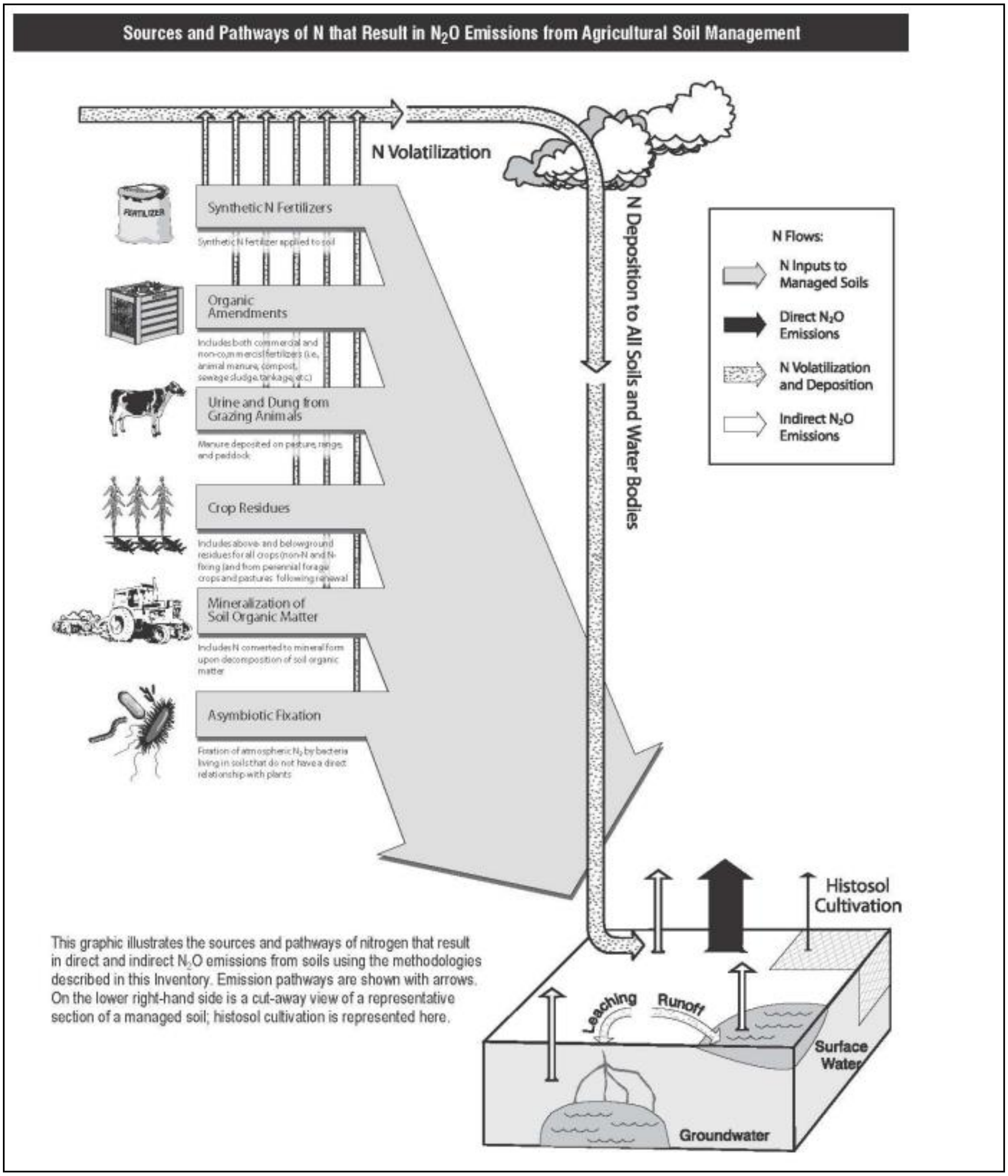
Soil Cultivation - Nitrous Oxide (N_2O)

N_2O is also emitted during the cultivation of highly organic soils called histosols. May 2011 soil survey data from the Natural Resources and Conservation Service shows there are just over 70,000 acres of histosols in Iowa (Sucik 2011a and 2011b). The quantity of histosols that are cultivated is not currently

[2] SIT uses the category of market swine under 60 lbs., but USDA uses the category of market swine under 50 lbs.
[3] SIT uses the category of market swine 60 – 119 lbs., but USDA uses the category of market swine 50 - 119 lbs.

available (Bedmarek 2012), so the DNR estimated the number of cultivated histosols acres by multiplying the acres of histosols by the annual percentages of Iowa cropland that are corn and soybeans (USDA 2019b) and by the average percentage of each crop that is tilled (Sucik 2011b). However, this may be an overestimation as according to former State Soil Scientist, Michael Sucik, "…all Histosols are listed as hydric soils and are eligible for the Wetland Restoration Program as CRP [Conservation Reserve Program] practices that require wetlands. Also, a histosol would require some type of artificial drainage in order to be consistently row cropped" (Sucik 2011a).

Figure 1: Sources and Pathways of N_2O Emissions in Ag Soils (EPA 2016)



Soil Tillage Practices

Carbon may be emitted when soils are tilled. However, carbon may also be sequestered when soil conservation practices are used (no-till or reduced tillage), when cropland is enrolled in the Conservation Reserve Program, or when cropland is converted to grass, trees, or wetlands. This balance between emissions and sequestration is called the soil carbon flux. In the past, the SIT did not include the ability to calculate emissions from soil carbon flux from tillage practices. Although this feature was added in 2018, the DNR has not had sufficient time to evaluate its methods and use. If resources allow, it may be used in future GHG inventories.

Practicing no-till for many consecutive years produces the greatest carbon sequestration. When soil is tilled, the soil becomes oxygenated, increasing microbial activity and releasing stored carbon. However, the amount of carbon stored and released is uncertain. Scientific studies and literature reviews, such as those by Baker et al. (2007), Blanco-Canqui, and Lal (2008), have created uncertainty in this area, while other studies such as those by Franzluebbers (2009) and Boddey et al (2009) dispute them. According to the USDA's "*'No-Till" Farming is a Growing Practice",* there is much uncertainty in the interaction between tillage practices, carbon, and other greenhouse gases" (USDA 2010). A 2007 study by West and Six explains that, "*The extent to which soil C accumulation occurs after a reduction in tillage intensity is determined by the history of land management, soil attributes, regional climate, and current carbon stocks"* (West and Six 2007). The relationship between tillage and nitrogen oxides (N_2O) is also not completely certain. Several studies have observed increases, decreases, and no change in N_2O when soil is tilled (USDA 2010).

The complexity of calculating soil carbon flux is described in USDA's *Science-Based Methods for Entity-Scale Quantification of Greenhouse Gas Sources and Sinks from Agriculture and Forestry Practices*. This 605-page document was developed to create "a standard set of GHG estimation methods for use by USDA, landowners, and other stakeholders to assist them in evaluating the GHG impacts of their management decisions" (Eve 2014). It recommends that soil organic carbon stocks be calculated by modeling with the DAYCENT model. At this time, the DNR does not have the required data inputs or the capability to run the DAYCENT model.

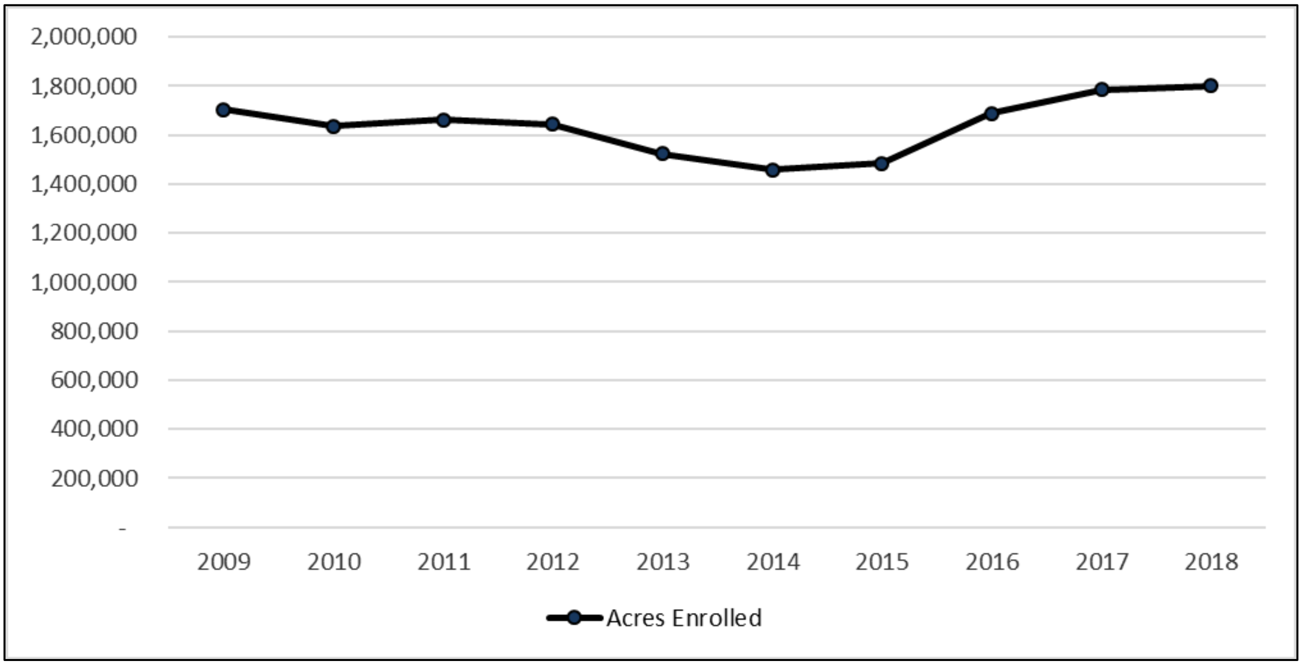
The USDA has also established seven regional climate change offices, offering climate hazard and adaptation data and services to farmers, ranchers, and forest landowners. The NRCS, a department within the USDA, has also launched a program called Carbon Management and Evaluation Online Tool (COMET-FARM) that allows users to calculate how much carbon is removed from the atmosphere from certain conservation efforts. The COMET-FARM website explains that:

> *The tool guides you through describing your farm and ranch management practices including alternative future management scenarios. Once complete, a report is generated comparing the carbon changes and greenhouse gas emissions between your current management practices and future scenarios (NRCS 2015).*

COMENT-FARM is not designed to calculate statewide greenhouse gas emissions from farming and ranching. It requires specific data inputs for each individual farm. However, if NRCS should publish results from the tool in the future, the DNR may include them in future inventory reports.

While the DNR is unable to quantify the statewide total agricultural soil carbon flux at this time, it may correlate with the cumulative Iowa acres enrolled in the CRP program shown in Figure 2. However, effects from cover crops may alter the relationship, but were not considered. This may be a future inventory improvement project.

Figure 2: Iowa Acres Enrolled in CRP by Fiscal Year (USDA 2018b, 2019a)



Fertilizer Utilization

The DNR calculated fertilizer emissions for 2017 using fertilizer tonnages from the Iowa Department of Agriculture and Land Stewardship's (IDALS) *Fertilizer Tonnage Distribution in Iowa* report (IDALS 2017). The IDALS fertilizer data is provided per the 2017 growing season, which is from July 2016 – June 2017. IDALS no longer supports the *Fertilizer Tonnage Distribution in Iowa* report (Krutzfeldt 2019), and more current data are not available in the 2018 Iowa Agricultural Statistics Bulletin (USDA 2018a). Therefore, the 2017 growing season was then used as a proxy for the 2018 growing season (July 2017 – June 2018) and first half of the 2019 growing season (July 2018 – December 2018).

Adjustments

Since the DNR's 2017 GHG Inventory Report was published in December 2018, the 2017 emissions from enteric fermentation, manure management, and agricultural soils have been updated using revised activity data (such as animal populations or fertilizer application) from USDA or IDALS as follows:

- Populations of goats, horses, and poultry from the 2017 Census of Agriculture (USDA 2019b) were used for 2017 instead of using the 2012 Census of Agriculture populations as a proxy for 2017 data.
- 2017 populations of bulls, steer stockers, heifer stockers, market swine and breeding swine were updated to match revised values in the 2018 Iowa Annual Statistics Bulletin (USDA 2018a).
- Values of tons of barley produced, tons of sorghum for grain produced, tons of rye produced, acres of barley harvested, and acres of sorghum for grain harvested from the 2017 Census of Agriculture (USDA

2019b) were used for 2017 instead of using the 2012 Census of Agriculture populations as a proxy for 2017 data, as was done in the previous inventory.

- Tons of soybeans produced, acres of soybeans harvested, and acres of corn harvested in 2017 were updated to match revised values in the USDA's Quick Stats database (USDA 2019b)

Table 11: Recalculated Agricultural Emissions (MMtCO$_2$e)

Category	2017 Value (Published Dec. 2018)	2017 Updated Value
Enteric Fermentation	8.33	8.40
Manure Management	11.58	11.75
Agricultural Soils	19.71	21.56
Total	**39.61**	**41.71**

Results

GHG emissions from agriculture decreased 0.19% from 2017 – 2018 but increased 14.13% from 2009 – 2018. Gross GHG emissions from agriculture were 41.63 MMtCO$_2$e in 2018, or 30.28% of Iowa's total gross GHG emissions. This total does not account for any carbon sinks from agriculture. Sinks are discussed in *Chapter 9 – Land Use, Land Use Change, and Forestry*. Just over half of the agricultural emissions (51.59%) are from soils as shown in Figure 3 and Table 6.

Figure 3: Gross GHG Emissions from Agriculture (MMtCO$_2$e)

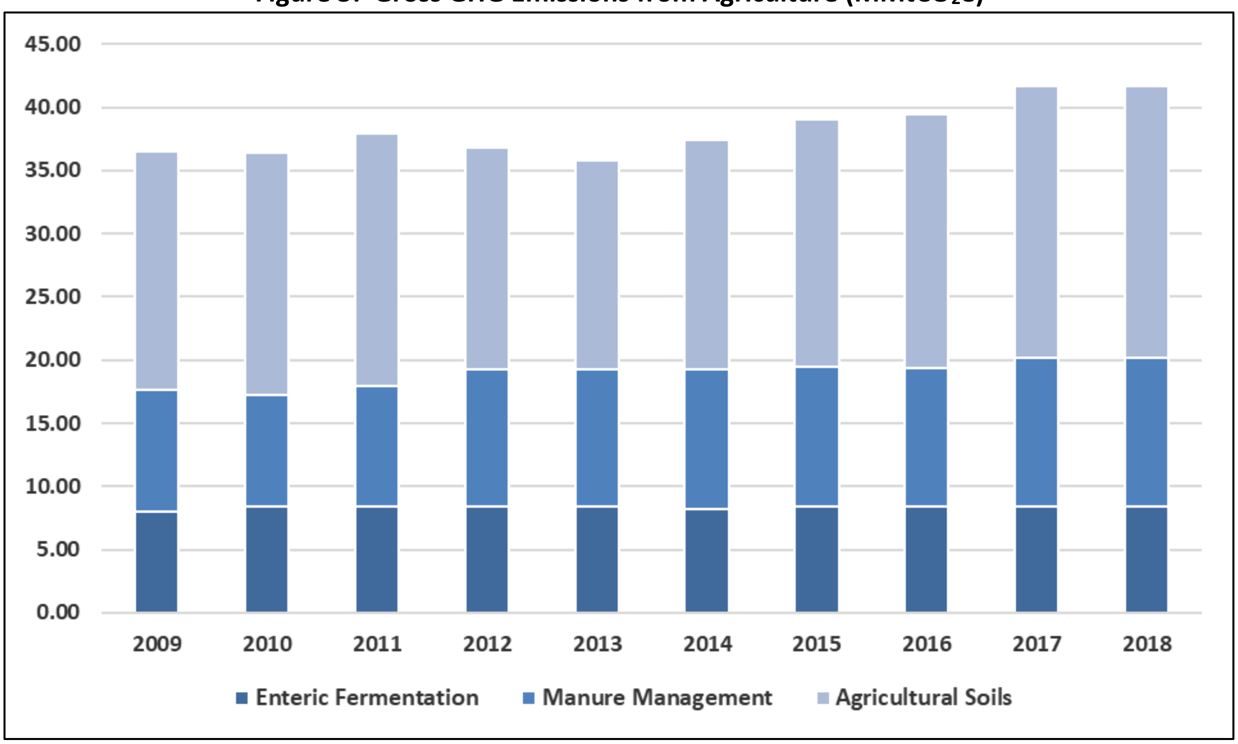


Table 6: Gross GHG Emissions from Agriculture ($MMtCO_2e$)[4]

Category	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Enteric Fermentation	8.02	8.39	8.41	8.40	8.38	8.19	8.36	8.43	8.40	8.45
Manure Management	9.59	8.83	9.53	10.86	10.85	10.42	11.07	10.96	11.75	11.70
Agricultural Soils	18.87	19.16	19.98	17.53	16.55	18.14	19.58	20.09	21.56	21.48
Total	**36.48**	**36.38**	**37.91**	**36.78**	**35.77**	**36.75**	**39.00**	**39.49**	**41.71**	**41.63**

Enteric Fermentation

CH_4 emissions from enteric fermentation were 8.45 $MMtCO_2e$ in 2018, increasing 0.57% from 2017. This can be attributed to a 4.16% increase in the total cattle population. While poultry and swine make up the greatest percentages of total livestock in Iowa as shown in Figure 4, enteric fermentation emissions are primarily driven by cattle. This is because cattle emit more CH_4 than other ruminant animals due to their unique stomach. In addition, poultry do not emit methane through enteric fermentation. The amount of methane emitted from each animal type is shown in Table 7.

Figure 4: 2018 Iowa Animal Populations (USDA 2018a, 2019b)[5]

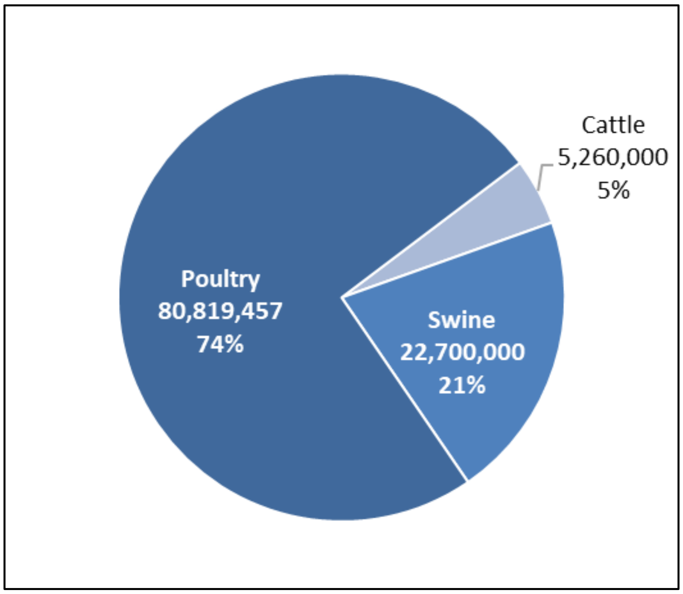


Table 7: Methane Emitted per Animal

Animal Type	kg/head CH_4 Emitted (ICF 2018a)
Beef Cattle	42.0 – 95.1
Dairy Cattle	43.2 – 139.7
Goats	5.0
Horses	18.0
Sheep	8.0
Swine	1.5

Manure Management

Factors influencing CH_4 and N_2O emissions include the animal type, animal population, animal mass, the type of manure management system, etc. GHG emissions from manure management decreased 0.39% from 2017 and

[4] Totals may not equal the sum of subtotals shown in this table due to independent rounding.
[5] The goat, horse, and sheep population each account for less than 1% of the total animal population.

accounted for 28.11% of agricultural GHG emissions in 2018. The decrease in emissions in 2018 can be linked to a decrease of 200,000 swine, as pigs accounted for 91.37% of the total emissions from manure management.

Agricultural Soils

The majority of GHG emissions from agricultural soils can be attributed to crop production (fertilizers, crop residues, and nitrogen fixing) as shown in Figure 5. Production of Iowa's two primary crops – corn and soybeans – decreased in 2018, as did production of alfalfa, oats, and wheat as shown in Table 8. This led to an overall decrease in N_2O emissions from agricultural soils of 0.19% from the previous year. N_2O emissions from agricultural soils accounted for 51.59% of all agricultural GHG emissions and 15.62% of total statewide GHG emissions in 2018.

Figure 5: 2017 - 2018 Gross GHG Emissions from Agricultural Soils (metric tons N_2O)

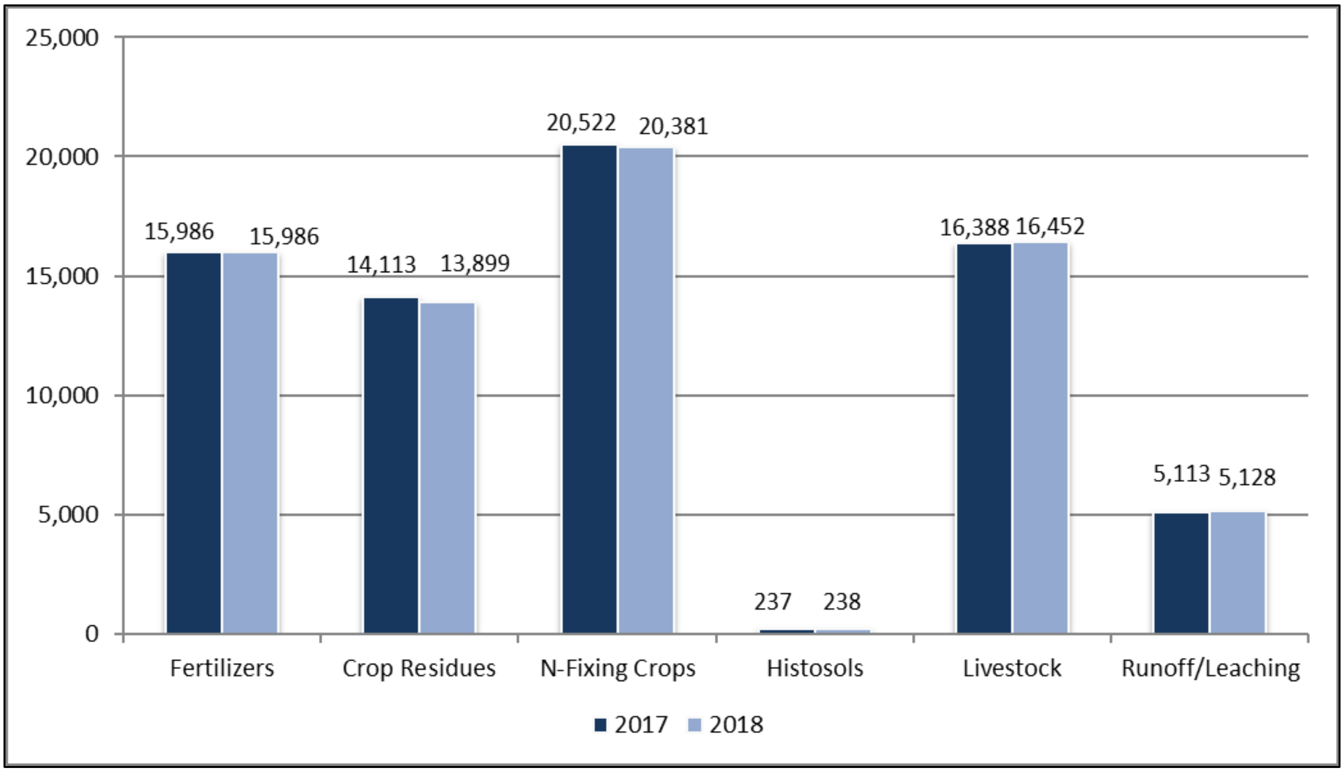


Table 8: Iowa Crop Production 2017 – 2018 (USDA 2019b)

Crop	2017 (1000 Bushels)	2018 (1000 Bushels)
Barley	54	54
Corn for Grain	2,605,800	2,508,800
Oats	3,234	2,079
Rye	247	247
Sorghum for Grain	25	25
Soybeans	566,580	564,870
Wheat	544	348
Total	**3,176,485**	**3,076,424**
Crop	**2017 (1000 tons)**	**2018 (1000 tons)**
Alfalfa	2,520	2,294
Crop	**2017 (1000 CWT)**	**2018 (1000 CWT)**
Peas, Dry Edible	11	11

Uncertainty[6]

Enteric Fermentation

The quantity of methane (CH_4) emitted from enteric fermentation from livestock is dependent on the quality of the animal population estimates and the emission factors used for each animal type. Uncertainty is also introduced as animal populations are not constant, but vary throughout the year. There is also uncertainty associated with the original population survey methods used by USDA. The emission factors for a given animal type are also inherently uncertain, due to differences in production methods, environment, diet characteristics, and genetics (ICF 2018a).

Manure Management

As with enteric fermentation, uncertainty occurs in animal populations and the emission factors used for each animal. However, the largest contributor to uncertainty in manure management emissions in the SIT is the lack of Iowa-specific data describing manure management systems and the CH_4 and N_2O emission factors used for these systems. In addition, there is uncertainty in the maximum CH_4 producing potential (B_0) used for each animal group. This value varies with both animal and diet characteristics, so estimating an average across an entire population introduces uncertainty. While the B_0 values used in the SIT vary by animal subcategory to attempt to represent as many of these differences as possible, there is not sufficient data available at this time to estimate precise values that accurately portray the B_0 for all animal types and feeding circumstances (ICF 2004).

Agricultural Soils

The N_2O emissions from managed soils is dependent on a large number of variables other than N inputs. They include soil moisture, pH, soil temperature, organic carbon availability, oxygen partial pressure, and soil amendment practices. The effect of the combined interaction of these variables on N_2O flux is complex and highly uncertain. The methodology used in the SIT is based only on N inputs, does not include other variables, and treats all soils, except histosols, equally. In addition, there is limited knowledge regarding N_2O productions from soils when N is added to soils. It is not possible to develop emission factors for all possible combinations of soil, climate, and management conditions.

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[6] This information is largely excerpted from the *SIT Agriculture Module* (ICF 2018a).

Uncertainties also exist in fertilizer usage calculations. The fertilizer usage does not include non-commercial fertilizers other than manure and crop residues, and site-specific conditions are not considered in determining the amount of N excreted from animals. Additional uncertainty occurs due to lack of Iowa-specific data for application of sewage sludge and cultivation of histosols.

Chapter 3 – Fossil Fuel Consumption

This chapter includes GHG emissions from fossil fuel consumption in four categories: power plants, residential, industrial, and commercial. The residential, commercial, and industrial categories are often combined into one category called RCI. Fossil fuels combusted by mobile sources are included in the transportation sector and discussed in *Chapter 6 – Transportation*. Emissions from the electric generation category include direct emissions resulting from the combustion of fossil fuels at the electric generating station (i.e. power plant). Indirect emissions from electricity consumed at the point of use (i.e. residential electric water heaters) are discussed in *Chapter 10 – Indirect Emissions from Electricity Consumption*.

Method

Residential, Commercial, Industrial (RCI)

GHG emissions were calculated using two SIT modules – the CO_2FFC module for carbon dioxide (CO_2) emissions and the Stationary Combustion module for CH_4 and N_2O emissions (ICF 2018a-d). These modules calculate energy emissions based on annual statewide consumption for the sectors and fuels listed in Table 9:

Table 9: Fuel Types Included in Fossil Fuel Consumption

Fuel Types	Residential	Commercial	Industrial
Asphalt/Road oil			x
Aviation gasoline blending components			x
Coal	x	x	x
Coking coal, other coal			x
Crude oil			x
Distillate fuel oil	x	x	x
Feedstocks			x
Kerosene	x	x	x
LPG	x	x	x
Lubricants			x
Misc. petroleum products			x
Motor gasoline		x	x
Motor gasoline blending components			x
Natural gas	x	x	x
Pentanes plus			x
Petroleum coke			x
Residual fuel		x	x
Still gas			x
Special naphthas			x
Unfinished oils			x
Waxes			x
Wood	x	x	x

Iowa-specific 2018 energy consumption data will not be published by the U.S. Energy Information Administration until June 2020, so the DNR projected 2018 energy consumption. This was done by using the EIA's *Annual Energy Outlook (AEO) 2019 with Projections to 2050* (EIA 2019a) and 2017 bulk energy consumption data from the EIA's State Energy Data System (SEDS) (EIA 2019b). The AEO2019 includes several different projection cases, each addressing different uncertainties. The DNR used the AEO2019 "Reference Case," which models projections of what may happen given certain assumptions and methodologies. The AEO uses the

National Energy Modeling System (NEMS), which has the objective to show various interactions of economic changes and energy supply, demand, and prices (EIA 2019a). The projections in the Reference Case are done at the regional level, and Iowa is in the West North Central U.S. Census Region. The 2018 energy consumption was estimated for each fuel type using one of two methods as described below and shown in Table 10:

Fuel Method 1

The percent change in the regional consumption of each fuel type in the AEO2019 was calculated. The percent change was then applied to the Iowa 2017 fuel consumption in SEDS. This method was used for the fuel types listed in Table 10.

Fuel Method 2

These sectors were not included in the AEO Reference Case, so it was assumed that 2018 fuel consumption was equal to the 2017 fuel consumption. This method was used for the fuel types listed in Table 10.

Table 10: Method Used to Estimate 2018 Fuel Consumption

Fuel Type	Estimation Method
Commercial Coal	Method 1
Commercial Distillate Fuel Oil	Method 1
Commercial Kerosene	Method 1
Commercial LPG	Method 1
Commercial Motor Gasoline	Method 1
Commercial Natural Gas	Method 1
Industrial Coal	Method 1
Industrial Distillate Fuel Oil	Method 1
Industrial LPG	Method 1
Industrial Motor Gasoline	Method 1
Industrial Natural Gas	Method 1
Industrial Other Coal	Method 1
Industrial Residual Oil	Method 1
Residential Distillate Fuel	Method 1
Residential LPG	Method 1
Residential Natural Gas	Method 1
Commercial Coal	Method 1
Commercial Residual Fuel	Method 2
Commercial Wood	Method 2
Industrial Asphalt and Road Oil	Method 2
Industrial Aviation Gasoline Blending Components	Method 2
Industrial Coking Coal	Method 2
Industrial Crude Oil	Method 2
Industrial Feedstocks, Naphtha less than 401 F	Method 2
Industrial Feedstocks, Other Oils greater than 401 F	Method 2
Industrial Kerosene	Method 2
Industrial Lubricants	Method 2
Industrial Misc. Petro Products	Method 2
Industrial Motor Gasoline Blending Components	Method 2
Industrial Pentanes Plus	Method 2
Industrial Petroleum Coke	Method 2

Fuel Type	Estimation Method
Industrial Special Naphthas	Method 2
Industrial Still Gas	Method 2
Industrial Unfinished Oils	Method 2
Industrial Waxes	Method 2
Industrial Wood	Method 2
Residential Coal	Method 2
Residential Kerosene	Method 2
Residential Wood	Method 2

Power Plants

Emissions from electricity generation at power plants were not calculated using fuel consumption data. Depending on the year, emissions from either EPA's Clean Air Markets Division (CAMD 2019) or EPA's federal GHG Reporting Program (EPA 2019) were used as follows:

2005 – 2009

CO_2 emissions reported to EPA by individual facilities subject to CAMD's reporting requirements (generally speaking, those power plants that serve a generator with a nameplate capacity greater than 25 megawatts and sell at least one-third of their electricity to the grid) were used. This data is more accurate than the values from EIA because the CO_2 emissions reported by facilities to CAMD are actual measured emissions values from continuous emission monitoring systems (CEMS) located on electric generating units.

2010 - 2018

Power plants became subject to the federal GHG reporting program starting with calendar year 2010. Facilities are required to report CO_2, CH_4, and N_2O emissions. This CO_2 data is also from CEMS and is more accurate than EIA data. In addition, the CH_4 and N_2O emissions are calculated using facility-specific fuel heating values. The CO_2 data reported to the federal GHG reporting program is consistent with the CO_2 emissions reported by the same facilities to CAMD.

Adjustments

The DNR previously forecasted 2017 emissions from RCI due to a lack of Iowa-specific energy consumption data. However, the 2017 energy data was released by EIA in June 2019 (EIA 2019b), so the DNR used the data to recalculate 2017 emissions as shown in Table 11.

Table 11: Recalculated RCI Emissions (MMtCO$_2$e)

Category	2017 Value (Published Dec. 2018)	2017 Updated Value
Residential	4.84	4.41
Commercial	3.77	3.82
Industrial	21.21	23.82
Total	**29.81**	**32.05**

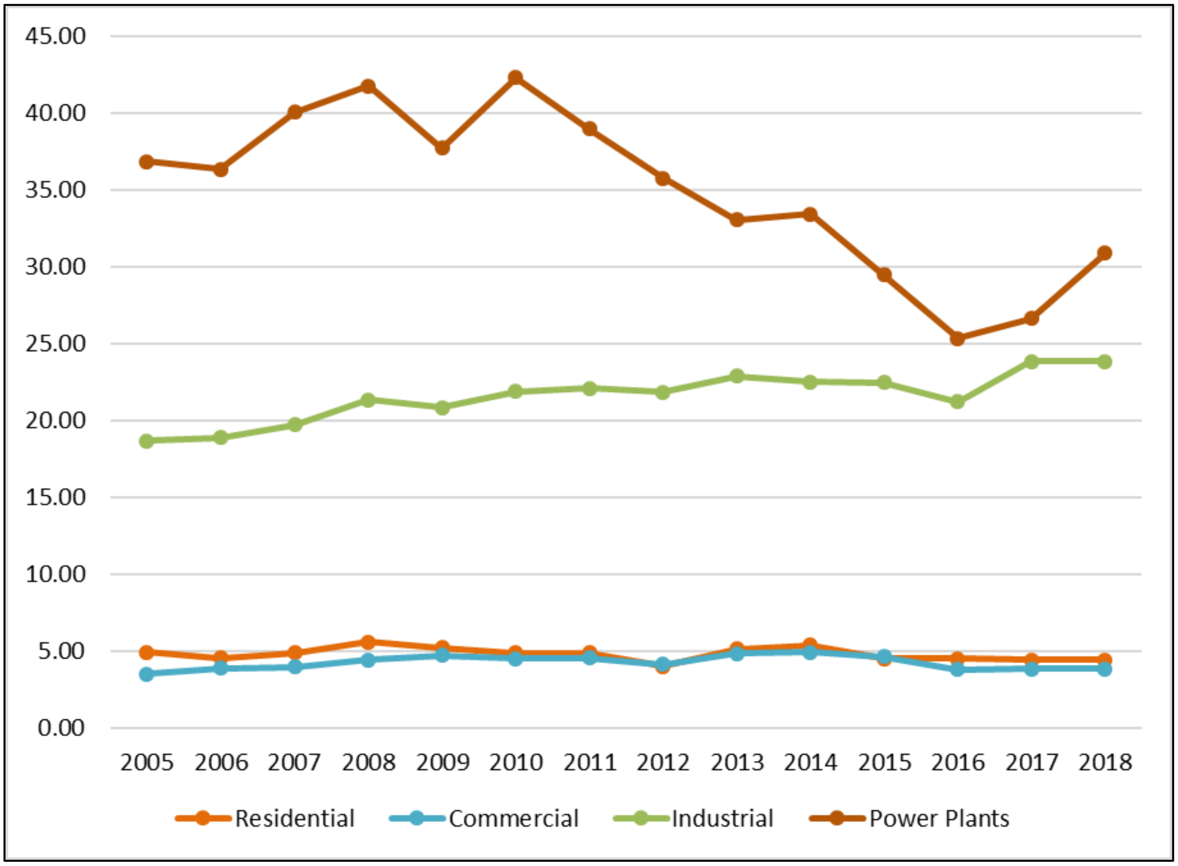
Results

Total GHG emissions from fossil fuel consumption in 2018 were 62.93 MMtCO$_2$e, an increase of 7.26% from 2017 and a decrease of 8.06% from 2009 levels as shown in Table 12 and Figure 6. Emissions from three categories (residential, commercial, and industrial fuel use) changed little from the previous year (+0.01% – +0.10%), while emissions from power plants increased by 4.25 $MMtCO_2e$ (15.97%).

Table 12: GHG Emissions from Fossil Fuel Consumption by Category ($MMtCO_2e$)[7]

Category	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Residential	5.21	4.88	4.85	4.01	5.12	5.38	4.49	4.48	4.41	4.41
Commercial	4.70	4.48	4.52	4.11	4.83	4.92	4.60	3.77	3.82	3.83
Industrial	20.82	21.88	22.07	21.84	22.87	22.52	22.44	21.21	23.82	23.83
Power Plants	37.71	42.33	38.98	35.76	33.06	33.44	29.46	25.33	26.62	30.87
Total	**68.44**	**73.56**	**70.42**	**65.72**	**65.89**	**66.26**	**61.00**	**54.78**	**58.97**	**62.93**

Figure 6: GHG Emissions from Fossil Fuel Consumption by Category ($MMtCO_2e$)



As noted above, emissions from fossil-fuel fired power plants increased 15.97%. This is due to an increase in electrical generation from fossil fuels. Factors contributing to that increase may include:

- more efficient power plants operated more hours
- differences in how electricity generation was dispatched by the Midcontinent Independent System Operator (MISO) in 2018 compared to 2017
- differences in temperatures and wind conditions in 2018 compared to 2017

[7] Values do not include emissions from the transportation sector. Totals may not equal the sum of subtotals shown in this table due to independent rounding.

- differences in electricity demand by customers
- other market forces and factors

CO_2 Uncertainty[8]

The amount of CO_2 emitted from energy consumption depends on the type and amount of fuel that is consumed, the carbon content of the fuel, and the fraction of the fuel that is oxidized. Therefore, the more accurate these parameters are, the more accurate the estimate of direct CO_2 emissions will be. Nevertheless, there are uncertainties associated with each of these parameters.

More uncertainty exists in state-level data than national total energy consumption data, especially when allocating consumption to the individual end-use sectors (i.e. residential, commercial, and industrial). The amount or rate at which carbon is emitted to the atmosphere can vary greatly depending on the fuel and use, and may vary at the state-level compared to the national default levels in the SIT.

The uncertainty in carbon content and oxidation are much lower than with fuel consumption data. Carbon contents of each fuel type are determined by EIA by sampling and the assessment of market requirements, and, with the exception of coal, do not vary significantly from state to state. EIA takes into account the variability of carbon contents of coal by state; these coefficients are also provided in the SIT.

Uncertainty is also introduced by the complexity in calculating emissions from the import/export of electricity. The precise fuel mix used to generate the power crossing state lines is very difficult to determine, so, an average fuel mix for all electricity generation within a specific region of the grid must usually be used. Moreover, these emissions factors are generated by emission monitors (rather than carbon contents of fuels), which may overestimate CO_2 emissions to a small extent.

CH_4 and N_2O Uncertainty[9]

The amount of CH_4 and N_2O emitted depends on the amount and type of fuel used, the type of technology in which it is combusted (e.g., boilers, water heaters, furnaces), and the type of emission control used. In general, uncertainty is improved by using more detailed combustion activity information. However, as noted in the Revised 1996 IPCC Guidelines (IPCC/UNEP/OECD/IEA 1997), the contribution of CH_4 and N_2O to overall emissions is small and the estimates are highly uncertain.

Uncertainties also exist in both the emission factors and the EIA energy consumption data used to calculate emissions. For example, the EIA state-specific datasets do not fully capture the wood used in fireplaces, wood stoves, and campfires. As with CO_2, uncertainty is also introduced with allocating energy consumption data to the individual end-use sectors and estimation of the fraction of fuels used for non-energy.

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[8] This information is largely excerpted from the *SIT CO_2FFC Module* (ICF 2018a).

[9] This information is largely excerpted from the *SIT Stationary Combustion Module* (ICF 2018b).

Chapter 4 - Industrial Processes

This chapter includes non-combustion GHG emissions from a variety of industrial processes. The processes and GHG pollutants emitted from each category are shown in Table 13. Emissions from these industries do not include emissions from fossil fuel combustion, which are included in *Chapter 3 – Fossil Fuel Combustion.*

Table 13: Industrial Processes and GHG Emissions

Category	GHGs Emitted
Ammonia Production & Urea Consumption	CO_2
Cement Production	CO_2
Electric Power Transmission & Distribution	SF_6
Iron and Steel Production	CO_2
Lime Manufacture	CO_2
Limestone and Dolomite Use	CO_2
Nitric Acid Production	N_2O
Ozone Depleting Substances (ODS) Substitutes	HFCs, PFCs, and SF_6
Semiconductor Manufacturing	HFCs, PFCs, and SF_6
Soda Ash Use	CO_2

Ammonia Production and Urea Consumption

CO_2 is released during the manufacture of ammonia. The chemical equations to calculate the release of CO_2 are complex, but in general, anhydrous ammonia is synthesized by reacting nitrogen with hydrogen. The hydrogen is typically acquired from natural gas. The majority of direct CO_2 emissions occur when the carbon in the natural gas is then eliminated from the process by converting it to CO_2. Other emissions of CO_2 can occur during condensate stripping or regeneration of the scrubbing solution. CO_2 emissions may also be captured for use in urea synthesis or carbon sequestration and storage (WRI 2008). Three facilities in Iowa currently produce ammonia.

Cement Production

Carbon Dioxide (CO_2) is emitted during a process called calcining when limestone is heated in a cement kiln to form lime and CO_2. The CO_2 is vented to the atmosphere and the lime is then mixed with silica-containing materials such as clay to form clinker, an intermediate product that is made into finished Portland cement (ICF 2004). Two facilities in Iowa currently produce Portland cement.

Electric Power Transmission and Distribution

Sulfur hexafluoride (SF_6) is used as an insulator in electricity transmission and distribution in equipment such as transformers, high-voltage circuit breakers, substations, and transmission lines (ICF 2018b).

Iron and Steel

Iron and steel production is an energy-intensive process that also generates process-related GHG emissions. Steel is produced from pig iron or scrap steel in a variety of specialized steel-making furnaces, including electric arc furnaces (EAFs) and basic oxygen furnaces (BOFs) (EPA 2016). There are currently no pig iron mills operating in Iowa. All three steel production facilities currently operating in Iowa use EAFs to produce steel from scrap. These furnaces use carbon electrodes, coal, natural gas, and other substances such as limestone and dolomite to aid in melting scrap and other metals, which are then improved to create the preferred grade of steel. In EAFs,

CO_2 emissions result primarily from the consumption of carbon electrodes and from the consumption of supplemental materials used to augment the melting process (EPA 2016).

Lime Manufacture
Similar to cement manufacturing, lime is produced by heating limestone in a kiln, creating lime and CO_2. The CO_2 is typically released to the atmosphere, leaving behind a product known as quicklime, which can then be used to produce other types of lime (ICF 2004). One facility currently manufactures lime in Iowa.

Limestone and Dolomite Use
Limestone and dolomite are used in industrial processes such as glass making, flue gas desulfurization, acid neutralization, etc.

Nitric Acid Production
Nitrous Oxide (N_2O) is produced when ammonia is oxidized to produce nitric acid. Two facilities in Iowa currently produce nitric acid.

Consumption of ODS Substitutes
Ozone Depleting Substances (ODS) are often used in refrigeration, air conditioning, aerosols, solvent cleaning, fire extinguishers, etc. However, ODS are being phased out per the Montreal Protocol and the 1990 Clean Air Act Amendments. The most common ODS are HFCs, but PFCs and SF_6 may also be used (ICF 2018b).

Semiconductor Manufacturing
Last year the DNR added emissions from semiconductor manufacturing to the inventory. It was previously assumed that semiconductors were not manufactured in Iowa. However, the 2017 Economic Census identifies eleven businesses in Iowa under the North American Industry Classification System (NAICS) for code 33441 – Semiconductor and Other Electronic Manufacturing (U.S. Census 2019b).

Soda Ash Use
Soda ash is currently only produced in three states – Wyoming, Colorado, and California. However, commercial soda ash is used as a raw material in a variety of industrial processes and in many familiar consumer products such as glass, soap, and detergents (ICF 2018b). In Iowa, it is commonly used by corn wet milling facilities for pH control, in ion exchange regeneration, and in other operations (DNR 2010).

Other Industry Types
GHG emissions from adipic acid production, (primary) aluminum production, HCFC-22 production, and magnesium production and processing were not calculated, as the DNR is not aware of any of these facilities currently operating in Iowa.

<u>Method</u>
The 2018 emissions from industrial processes were calculated using either the SIT (ICF 2018a) or using GHG emissions reported to EPA by individual facilities to the federal GHG reporting program (GHGRP) (40 CFR 98, EPA 2019a) as shown in Table 14.

Table 14: Industrial Processes Calculation Methods and Activity Data

Category	Year	Calculation Method	Data Source
Ammonia and Urea Production	2018	40 CFR 98 Subpart G	GHGRP (EPA 2019a)
Cement Production	2018	40 CFR 98 Subpart H	GHGRP (EPA 2019a)
Electric Power Transmission & Distribution	2017 as proxy for 2018	SIT	National GHG Inventory (EPA 2019b)
Iron and Steel Production	2018	40 CFR 98 Subpart Q	GHGRP (EPA 2019a)
Lime Manufacture	2018	40 CFR 98 Subpart S	GHGRP (EPA 2019a)
Limestone and Dolomite Use	2015 as proxy for 2016, 2017 & 2018	SIT	USGS 2017
Nitric Acid Production	2018	40 CFR 98 Subpart V	GHGRP (EPA 2019a)
ODS Substitutes	2017 as proxy for 2018	SIT	National GHG Inventory (EPA 2019b)
Semiconductor Manufacturing	2016 as proxy for 2017 and 2018	SIT	SIT defaults
Soda Ash Use	2018	SIT	(USGS 2019)

Categories Calculated using the SIT

Because current emissions data was not available for the electric power transmission and distribution, the 2017 national emissions were used as a proxy for 2018. The 2017 value was calculated by determining the ratio between 2017 Iowa retail sales to 2017 national retail sales (EIA 2019), and applying that ratio to 2017 national emissions of SF_6. The 2018 retail sales ratio was used for 2018.

Emissions in 2015 from the use of limestone and dolomite in industrial processes were used as a proxy for 2016, 2017, and 2018 emissions. The 2015 value was calculated by multiplying Iowa's 2015 consumption by the ratio of national consumption for industrial uses to total national consumption.

Emissions in 2017 from ODS substitutes and soda ash consumption were used as proxy for 2018. The 2017 and 2018 values were calculated by assuming that Iowa emissions were 0.96% of national emissions because Iowa's population is 0.96% of the total U.S. Population (U.S. Census 2019b).

Emissions in 2016 from semiconductor manufacturing were used as a proxy for 2017 and 2018. They were calculated by assuming that Iowa emissions were 0.96% of national emissions because Iowa's population is 0.96% of the total U.S. Population (U.S. Census 2019b).

Adjustments

Emissions from electric power transmission and distribution from 2013 - 2017 were recalculated as shown in Table 15, by using the most current national emissions data (EPA 2019b), adjusted for Iowa retail electricity sales compared to U.S. retail electricity sales. (EIA 2019).

Table 15: Recalculated Emissions from Electric Power T & D ($MMtCO_2e$)[10]

Year	2013	2014	2015	2016	2017
Value Published Dec. 2017	0.056	0.059	0.054	0.055	0.055

[10] DNR uses two decimal places throughout this report for consistency. However, in this sector three decimal places are needed show the difference in emissions from year to year.

Year	2013	2014	2015	2016	2017
Updated Value	0.055	0.058	0.051	0.055	0.056

Emissions from ODS substitutes from 2013 – 2017 were recalculated as shown in Table 15, by using the most current national emissions data (EPA 2019b), adjusted for Iowa population (U.S. Census 2019b).

Table 16: Recalculated Emissions from ODS Substitutes ($MMtCO_2e$)

Year	2013	2014	2015	2016	2017
Value Published Dec. 2017	1.51	1.57	1.64	1.63	1.63
Updated Value	1.39	1.42	1.47	1.47	1.47

Results

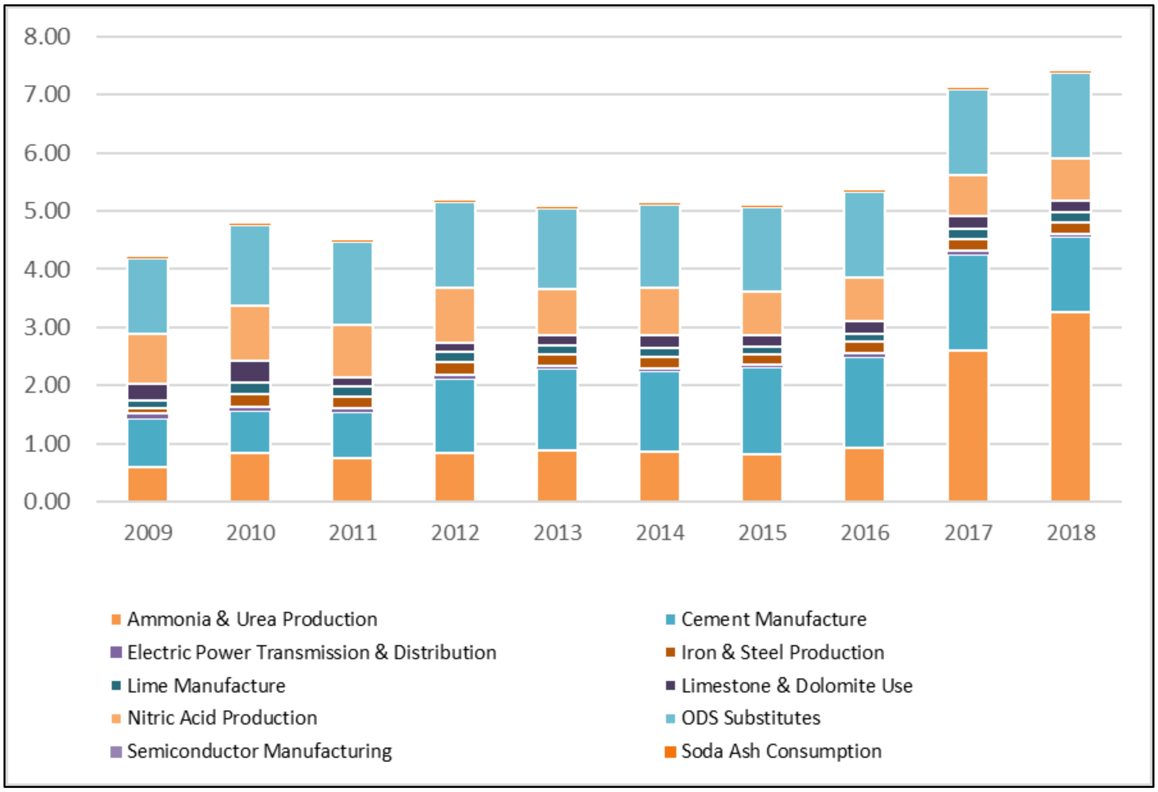
GHG emissions from industrial processes in 2018 were 7.40 $MMtCO_2e$, or 5.38% of total statewide GHG emissions. Emissions from this sector increased 4.20% from 2017 as shown in Table 17 and Figure 7, primarily due to a 25.27% increase in emissions from ammonia production (and a 21.65% decrease in emissions from cement manufacture). The emissions from three types of processes – ammonia and urea production, cement manufacture, and consumption of ODS substitutes, accounted for over 81.48% of the industrial process emissions in 2018.

Table 17: GHG Emissions from Industrial Processes ($MMtCO_2e$)[11]

Category	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Ammonia & Urea	0.60	0.84	0.75	0.85	0.88	0.86	0.81	0.92	2.60	3.26
Cement Manufacture	0.84	0.72	0.79	1.27	1.41	1.38	1.50	1.58	1.66	1.30
Electric Power T&D	0.07	0.07	0.07	0.06	**0.06**	**0.06**	**0.05**	**0.06**	**0.06**	0.06
Iron & Steel Production	0.09	0.23	0.20	0.23	0.19	0.18	0.16	0.19	0.20	0.19
Lime Manufacture	0.13	0.18	0.18	0.18	0.16	0.17	0.13	0.15	0.18	0.16
Limestone & Dolomite Use	0.29	0.39	0.16	0.15	0.18	0.21	0.21	0.21	0.21	0.21
Nitric Acid Production	0.87	0.95	0.90	0.96	0.80	0.82	0.74	0.75	0.70	0.73
ODS Substitutes	1.30	1.39	1.43	1.47	**1.39**	**1.42**	**1.45**	**1.47**	**1.47**	**1.47**
Semiconductor Manufacturing	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Soda Ash Consumption	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
Total	**4.21**	**4.79**	**4.50**	**5.18**	**5.07**	**5.12**	**5.09**	**5.34**	**7.10**	**7.40**

[11] Totals may not equal the sum of subtotals shown in this table due to independent rounding. Emissions from semiconductor manufacturing for each year 2008 – 2018 rounded to 0.001 $MMtCO_2e$ or less.

Figure 7: 2018 GHG Emissions from Industrial Processes (MMtCO$_2$e)



Uncertainty

Uncertainty occurs in categories where SIT default activity data was used instead of Iowa-specific activity data, such as limestone and dolomite use, soda ash use, ODS substitutes, and electric power transmission and distribution.

Other major sources of uncertainty associated with calculating emissions from industrial processes are listed below:[12]

- The estimation of emissions for limestone and dolomite use contains some inherent uncertainty based on limestone's variable composition.
- The use of population to disaggregate national emissions adds significant uncertainty.
- Uncertainties in emission estimates for electric power transmissions and distribution can be attributed to apportioning national emissions based on electricity sales. This method incorporates a low probability assumption that various emission reduction practices by industry occur evenly throughout the country.

[12] This information is largely excerpted from the *SIT Industrial Processes Module* (ICF 2018a).

Chapter 5 - Natural Gas Transmission & Distribution

This chapter includes GHG emissions from natural gas transmission and distribution (T & D) in Iowa. In this sector, methane (CH_4) is emitted from leaks, vents, regulators, valves, compressors, accidents, and other devices located along the natural gas transmission and distribution networks. Carbon dioxide (CO_2) emissions from venting and flaring was not calculated due to lack of data. GHG emissions from coal mining and natural gas production (including venting and flaring, oil production, oil transmission, and oil transportation), are not included as those activities are not currently taking place in Iowa.

Method

Natural Gas Transmission

Natural gas is transmitted in Iowa through large, high-pressure lines. These lines transport natural gas from production fields and processing plants located out-of-state to Iowa storage facilities, then to local distribution companies (LDCs) and high volume customers. Compressor stations, metering stations, and maintenance facilities are located along the transmission system. CH_4 is emitted from leaks, compressors, vents, and pneumatic devices (ICF 2018b).

The number of miles of transmission pipeline in Iowa was obtained from the United States Department of Transportation (DOT) Pipeline and Hazardous Materials Safety Administration's (PHMSA) Office of Pipeline Safety (DOT 2018). The Iowa Utilities Board confirmed that the number of natural gas compressor and gas storage stations did not change from the previous year (Munyon 2017).

Natural Gas Distribution

Natural gas is distributed through large networks of small, low-pressure pipelines. Natural gas flows from the transmission system to the distribution network at municipal gate stations, where the pressure is reduced for distribution within municipalities. CH_4 is emitted from leaks, meters, regulators, and accidents (ICF 2018b). Activity data from the DOT PHSMA's Office of Pipeline Safety was used for calculating emissions (DOT 2018). Data entered included miles of steel and cast iron distribution pipeline, unprotected and protected; number of services; and number of steel services, unprotected and protected.

Results

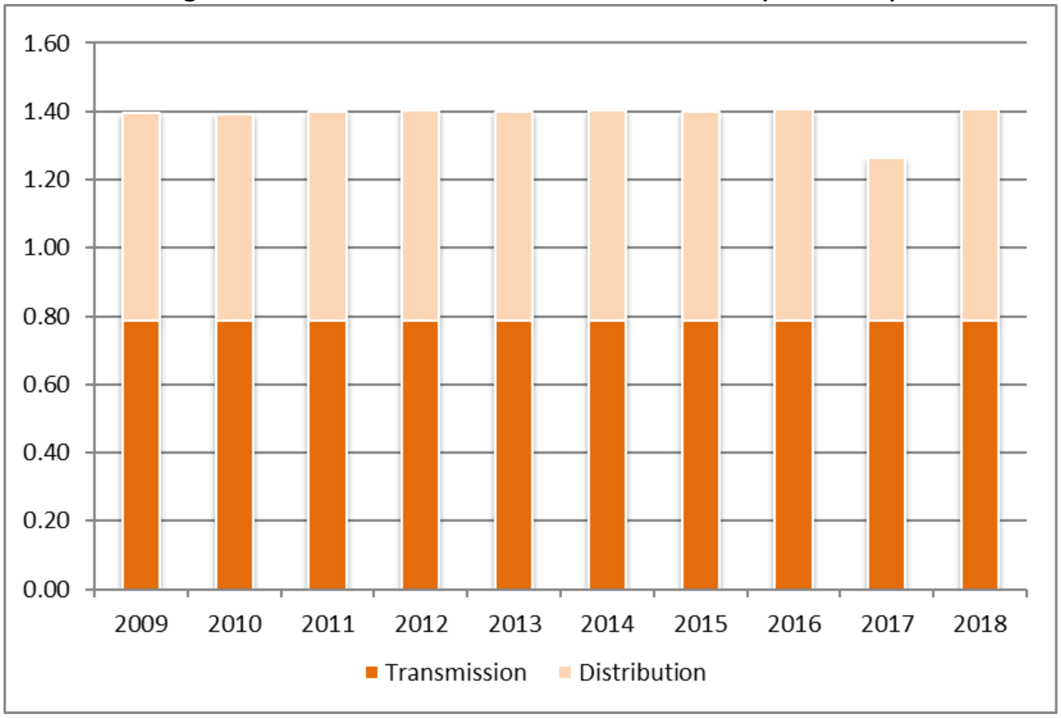
Total GHG emissions from natural gas transmission and distribution were 1.4073 $MMtCO_2e$[13] in 2018, an increase of 11.19% from 2017 and an increase of 0.87% from 2009 as shown in Table 18 and Figure 8. Emissions increased in 2017 due to increases in the miles of pipeline and number of services (e.g. gas meters) in the state. GHG emissions from this sector account for 1.02% of 2018 statewide GHG emissions.

Table 18: GHG Emissions from Natural Gas T & D ($MMtCO_2e$)

Category	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Transmission	0.7868	0.7871	0.7858	0.7862	0.7865	0.7864	0.7868	0.7867	0.7868	0.7864
Distribution	0.6084	0.6031	0.6132	0.6158	0.6135	0.6168	0.6118	0.6205	0.4789	0.6209
Total	**1.3952**	**1.3901**	**1.3990**	**1.4020**	**1.4000**	**1.4031**	**1.3986**	**1.4073**	**1.2657**	**1.4073**

[13] DNR uses two decimal places throughout this report for consistency. However, in this sector four decimal places are needed show the difference in emissions from year to year.

Figure 8: GHG Emissions from Natural Gas T & D ($MMtCO_2e$)



Uncertainty[14]

The main source of uncertainty in the SIT calculation methods is the emission factors. The emission factors used are based on a combination of statistical reporting, equipment design data, engineering calculations and studies, surveys of affected facilities and measurements. In the process of combining these individual components, the uncertainty of each individual component is pooled to generate a larger uncertainty for the overall emission factor. In addition, statistical uncertainties arise from natural variation in measurements, equipment types, operational variability, and survey and statistical methodologies. The method also does not account for regional differences in natural gas infrastructure and activity levels (ICF 2018a).

[14] This information is largely excerpted from the *SIT Natural Gas and Oil Systems Module* (ICF 2018a).

Chapter 6 - Transportation

This chapter includes GHG emissions from both highway and non-highway vehicles such as aviation, boats, locomotives, tractors, other utility vehicles, and alternative fuel vehicles.

Method

Emissions were calculated using the SIT Mobile Combustion module (ICF 2018a), which was updated by EPA in 2016 to calculate CO_2, CH_4, and N_2O emissions from highway vehicles based on vehicle miles traveled. This is a more accurate than previous methods as it accounts for the vehicle type and vehicle age in the calculation, as well as accounting for the annual vehicle miles traveled. Emissions from non-highway vehicles were calculated based on fossil fuel consumption.

Highway Vehicles (CH_4 and N_2O)

Highway vehicles include passenger cars, truck, motorcycles, and heavy-duty vehicles. CH_4 and N_2O emissions from highway vehicles were calculated using the SIT as follows:

1. The vehicle miles traveled (VMT) for each vehicle type was calculated using the total 2018 annual VMT of 33,507 million miles from the Iowa Department of Transportation (IDOT 2019). Neither the IDOT nor FHWA track state-level VMT by the seven classes used in the SIT. The state VMT was distributed among seven vehicle/fuel classes using the national distribution percentages from the Tables A-99 and A-100 from Annex 3 of the most recent national GHG inventory, *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2017* (EPA 2019). The classes and the national distribution percentages are shown in Table 19.

Table 19: VMT Vehicle/Fuel Classes and Distribution

Vehicle Class	Acronym	2017 (EPA 2019)	2018 Iowa VMT (10^6 miles)
Heavy duty diesel vehicle	HDDV	8.41%	2,818
Heavy duty gas vehicle	HDGV	1.06%	355
Light duty diesel truck	LDDT	0.78%	262
Light duty diesel vehicle	LDDV	0.33%	111
Light duty gasoline truck	LDGT	19.72%	6,608
Light duty gasoline vehicle	LDGV	69.07%	23,142
Motorcycle	MC	0.63%	211
Total		**100.00%**	**33,507**

2. The VMT was then converted for use with existing emission factors. Iowa-specific emission factors were not available, so the SIT default emission factors were used. These factors are consistent with those used in the most recent national GHG inventory.
3. Next, the VMT was allocated by model year. Iowa-specific VMT data by model year was not available, so the VMT was allocated using the default national on-road age distribution by vehicle/fuel type in the SIT. The “Annual Vehicle Mileage Accumulation” table in SIT was updated to match that in Table A-104 in the most recent national inventory (EPA 2019).
4. The control technology was then allocated by model year. Iowa-specific control technologies by model year were not available, so the national control technology values were used. The values in the SIT

matched the Tables A-107, A-108, and A-109 in Annex 3 of the most recent national inventory (EPA 2019).

Non-highway Vehicles (CH_4 and N_2O)
Non-highway vehicles include aviation, marine vessels, locomotives, and tractors. In general, CH_4 and N_2O emissions from non-highway vehicles were calculated using data from either the Energy Information Administration (EIA) or Federal Highway Administration as shown in Table 20.

Table 20: Iowa-specific Non-Highway Activity Data Used

Vehicle Type	Fuel Type	Year	Data Source
Aviation	Gasoline	2017 used as proxy for 2018	EIA SEDS (EIA 2019b)
Aviation	Jet Fuel, Kerosene		
Boats	Gasoline	2017 used as proxy for 2018	FHWA 2019
Heavy Duty Utility			
Tractors			
Construction			
Locomotives	Distillate Fuel	2017 used as proxy for 2018	EIA Adjusted Sales (EIA 2019a)
Tractors			
Construction	Distillate Fuel	2016 used as proxy for 2017-2018	SIT default value
Heavy Duty	Distillate Fuel		
Small Utility	Gasoline		
Alternative Fuel Vehicles			

Adjustments

Emissions from non-highway vehicles were recalculated for 2017 as shown in Table 21 by using updated fuel activity data from EIA and the FHWA.

Table 21: Recalculated Emissions from Transportation ($MMtCO_2e$)[15]

Pollutant	2017 Value (Published Dec. 2018)	2017 Updated Value
CO_2	20.17	20.25
CH_4	0.03	0.03
N_2O	0.15	0.14
Total	**20.34**	**20.42**

Results

Total GHG emissions from transportation were 20.40 $MMtCO_2e$ in 2018 as shown in Table 22. This is a decrease of 0.12% from 2017 and correlates to a 0.72% reduction in VMT from 2017 - 2018. CO_2 accounts for nearly all the Iowa transportation GHG emissions (99.93%) as shown in Figure 9. The majority of the transportation emissions (56.66%) are from gasoline highway vehicles as shown in Figure 10.

[15] Totals may not equal the sum of subtotals shown in this table due to independent rounding.

Table 22: GHG Emissions from Transportation ($MMtCO_2e$)[16]

Pollutant	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
CO_2	19.00	19.04	19.27	19.31	19.21	19.32	19.81	19.93	20.25	20.18
CH_4	0.04	0.04	0.04	0.04	0.04	0.04	0.03	0.03	0.03	0.03
N_2O	0.36	0.33	0.27	0.24	0.21	0.19	0.18	0.16	0.14	0.19
Total	**19.40**	**19.41**	**19.58**	**19.59**	**19.46**	**19.55**	**20.02**	**20.12**	**20.42**	**20.40**

Figure 9: Transportation Emissions by Pollutant ($MMtCO_2e$)

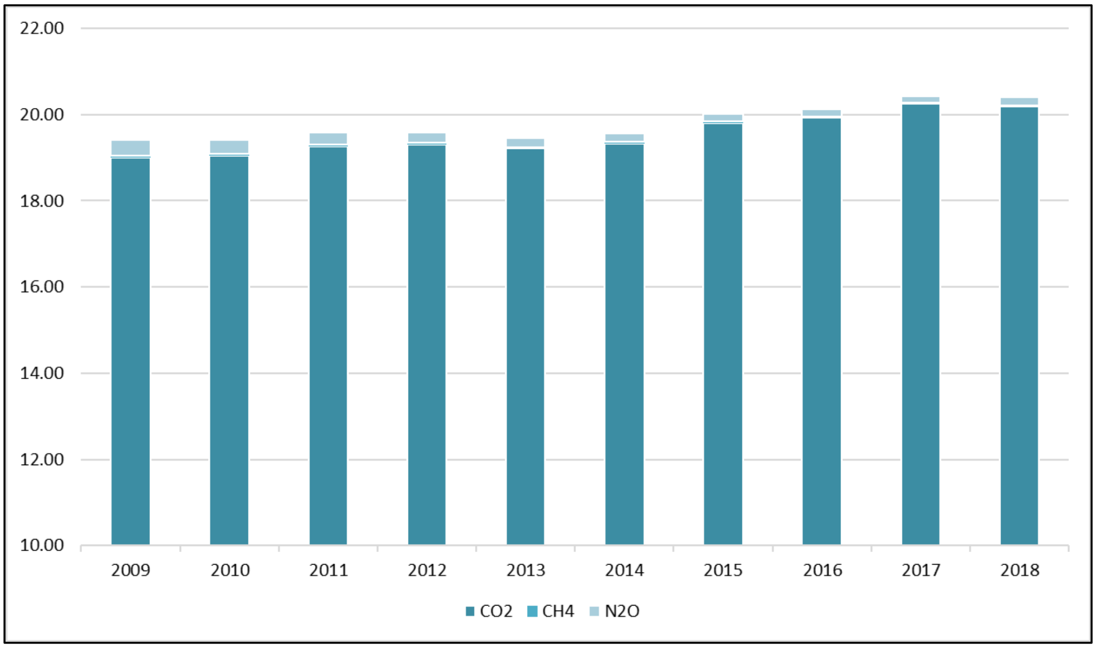
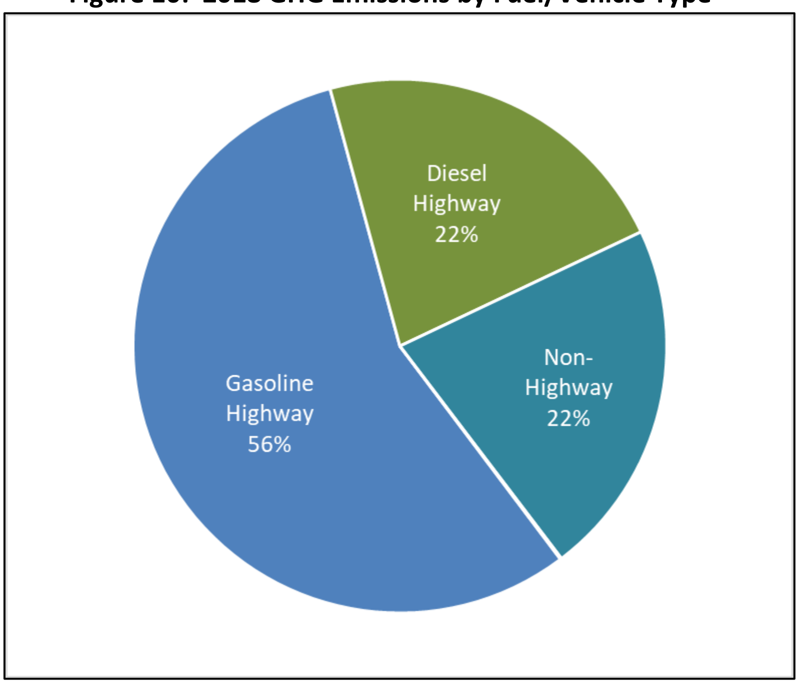


Figure 10: 2018 GHG Emissions by Fuel/Vehicle Type[17]



[16] Totals may not equal the sum of subtotals shown in this table due to independent rounding.
[17] Emissions from alternative vehicles round to 0%.

Uncertainty

Uncertainty occurs because national vehicle/fuel type, age distributions, and emission factors, which may not be reflective of Iowa conditions, were applied to Iowa-specific VMT data. There is also some uncertainty in the method EPA used to develop the national vehicle/fuel type distributions and to develop emission factors (EPA 2019). The VMT used for alternative fuel vehicles has a higher level of uncertainty because the DNR was unable locate Iowa-specific VMT data. Uncertainty may be introduced if the fuel consumption data or emission factors used do not reflect Iowa scenarios, such as using default national emission factors. In addition, it is assumed that all fuel purchased is consumed in the same year (ICF 2018b).

Chapter 7 – Waste: Solid Waste

This chapter includes methane (CH_4) emissions from municipal solid waste landfills and carbon dioxide (CO_2) and nitrous oxide (N_2O) emitted from the combustion of municipal solid waste to produce electricity. CH_4 emissions from landfills are a function of several factors, including:

- The total quantity of waste in municipal solid waste landfills,
- The characteristics of the landfills such as composition of the waste, size, and climate; the quantity of CH_4 that is recovered and flared, and
- The quantity of CH_4 oxidized in landfills instead of being released into the atmosphere.

Fluctuations in CH_4 emissions can be caused by changes in waste composition, the quantity of landfill gas collected and combusted, the frequency of composting, and the rate of recovery of degradable materials such as paper and paperboard (EPA 2011).

Method

Municipal Solid Waste (MSW) Landfills

The DNR used emissions reported by MSW landfills to the EPA GHGRP (EPA 2019), which are calculated based on the characteristics of each individual report. EPA requires MSW landfills that emit 25,000 metric tons CO_2e or more to report their emissions. This included twenty-four Iowa landfills in 2018. An additional twenty-two Iowa MSW landfills were not required to report to the GHGRP. To calculate emissions for those that did not report to the GHGRP, the DNR calculated the potential methane emissions using EPA's Landfill Gas Emissions Model (LandGEM) version 3.02. It is based on a first-order decomposition rate equation for quantifying emissions from the decomposition of landfilled waste in MSW landfills (EPA 2005).

Combustion of Municipal Solid Waste

The amount of CH_4 emitted from power plants burning MSW to produce electricity was calculated using data reported annually by individual facilities to the DNR's Air Quality Bureau on their annual air emissions inventories. One facility reported burning a total of 15,241 tons of municipal solid waste in 2019 (Reed 2019). The DNR used state-specific proportions of discards that are plastics, synthetic rubber, and synthetic fibers instead of SIT default values to calculate CO_2 emissions from MSW combustion using SIT (ICF 2017a). These state-specific proportion values are from the 2017 Iowa Statewide Waste Characterization Study (SCS 2017). The earlier, 2011 version of the study (MSW 2011), was used to calculate emissions from 2010 – 2016. The state-specific proportions of discards used are shown in Table 23.

Table 23: Proportions of Discards used in the Solid Waste Module

Material	SIT Default Value	2011 Iowa Study	2017 Iowa Study
Plastics	17.0 – 18.0%	16.7%	18.3%
Synthetic Rubber	2.3 – 2.6%	1.0%	1.2%
Synthetic Fibers	5.6 – 6.3%	4.1%	4.5%

Plastics and synthetic rubber materials may be further divided in the SIT into subcategories of plastics and rubber (e.g. polyethylene terephthalate (PET), polyvinyl chloride (PVC), polystyrene (PS), etc.), but the subcategories in the SIT do not match the subcategories in the waste characterization study. Therefore, the DNR did subcategorize the proportion of municipal solid waste discards.

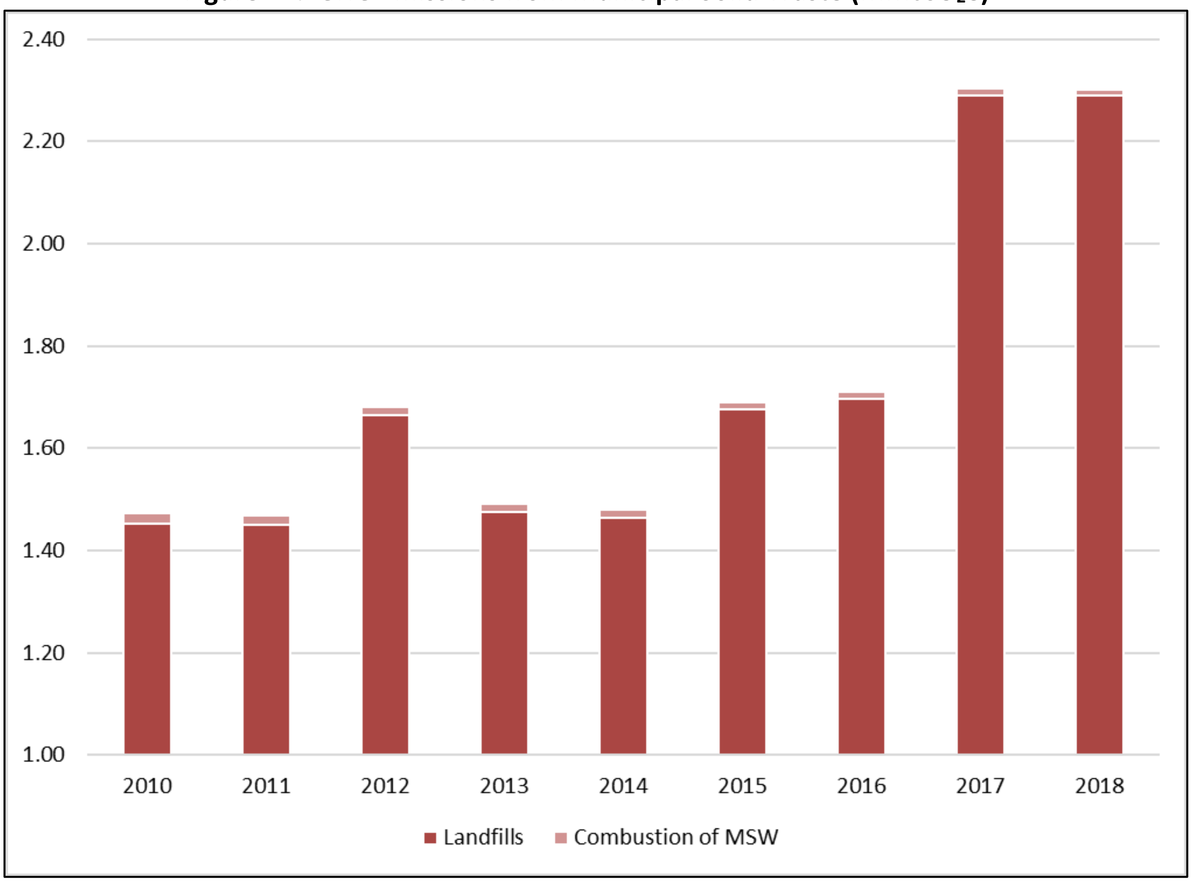
Results

Total GHG emissions from the solid waste category were 2.299 MMtCO_2e in 2018, a decrease of 0.14% from 2017 as shown in Table 24 and Figure 11. Solid waste emissions account for 1.67% of total statewide GHG emissions. Overall solid waste emissions decreased because emissions from combustion of MSW decreased 27.66%. Emissions from waste in landfills remained nearly constant (+0.01%) even though the cumulative amount of waste in landfills increased by 3.89% (DNR 2019). This is due to the length of time the waste is stored in the landfill and because the decomposition rate of the waste fluctuates according to the amount of waste in the landfill, the climate, the quantity of CH_4 that is recovered and flared, and varying oxidation rates.

Table 24: GHG Emissions from Municipal Solid Waste (MMtCO_2e)[18, 19]

Pollutant	2010	2011	2012	2013	2014	2015	2016	2017	2018
MSW Landfills	1.45	1.45	1.66	1.48	1.46	1.68	1.70	2.289	2.290
MSW Combustion	0.02	0.02	0.02	0.02	0.02	0.01	0.01	0.013	0.009
Total	**1.47**	**1.47**	**1.68**	**1.49**	**1.48**	**1.69**	**1.71**	**2.302**	**2.299**

Figure 11: GHG Emissions from Municipal Solid Waste (MMtCO_2e)[20]



[18] Totals may not equal the sum of subtotals shown in this table due to independent rounding.
[19] DNR uses two decimal places throughout this report for consistency. However, in this sector three decimal places are needed to show the difference in emissions from 2017 to 2018.
[20] Emissions from 2008 – 2009 are not included in the chart because they were calculated using the old method and are not directly comparable to emissions from 2010 – 2018.

<u>Uncertainty[21]</u>

MSW Combustion

There are several sources of uncertainty in this sector, including combustion and oxidation rates, average carbon contents, and biogenic content.

- The combustion rate is not exact and varies by the quantity and composition of the waste.
- The oxidation rate varies depending on the type of waste combusted, moisture content, etc.
- The SIT uses average carbon contents instead of specific carbon contents for other plastics, synthetic rubber, and synthetic fibers.
- Non-biogenic CO2 emissions vary depending on the amount of non-biogenic carbon in the waste and the percentage of non-biogenic carbon that is oxidized.

The SIT assumes that all carbon in textiles is non-biomass carbon and the category of rubber and leather is almost all rubber. This may result in CO_2 emissions being slightly over-estimated (ICF 2018b).

[21] This information is largely excerpted from the *SIT Solid Waste Module* (ICF 2018b).

Chapter 8 – Waste: Wastewater Treatment

This chapter includes GHG emissions from the treatment of municipal and industrial wastewater. The pollutants from this sector are methane (CH_4) and nitrous oxide (N_2O). CH_4 is emitted from the treatment of wastewater, both industrial and municipal. CH_4 is produced when organic material is treated in an anaerobic environment (in the absence of oxygen) and when untreated wastewater degrades anaerobically. N_2O is produced through nitrification followed by incomplete denitrification of both municipal and industrial wastewater containing both organic and inorganic nitrogen species. Production and subsequent emissions of N_2O is a complex function of biological, chemical, and physical factors, and emission rates depend on the specific conditions of the wastewater and the wastewater collection and treatment system. Human sewage makes up a signification portion of the raw material leading to N_2O emissions (ICF 2018b).

Method

Municipal Wastewater

GHG emissions from municipal wastewater are calculated in the SIT by multiplying a series of emission factors by the annual Iowa population, which was updated for 2018 (U.S. Census 2019). For example, to calculate CH_4 emissions, the state population was multiplied by the quantity of biochemical oxygen demands (BOD) per person emission factor, by the fraction that is treated anaerobically, and by the quantity of CH_4 produced per metric ton. It does not account for any digester methane that is collected and combusted instead of fossil fuels in equipment such as boilers, generators, or flares.

SIT default emission factors and assumptions were used to calculate both CH_4 and N_2O emissions, except that N_2O was calculated using the most recent protein (kg/person-year) value (44.3) from Table 7-16 in the *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2017* (EPA 2019b). The protein values for 2014 – 2017 have been updated by EPA and were used, resulting in annual decreases in emissions of 0.001 $MMtCO_2e$. Because the 2018 protein value was not available at the time of publication, the 2017 value was used as a surrogate for 2018.

The Iowa fraction of population without septic systems, 76%, from EPA's *Onsite Wastewater Treatment Systems Manual* (EPA 2002), was also used to estimate N_2O emissions. This value taken from the *1990 Census of Housing* and is lower than the SIT default value of 79%. The *2000 Census of Housing* and *2010 Census of Housing* do not include the Iowa fraction of population without septic systems.

Industrial Wastewater

In 2015, the DNR refined its method for calculating emissions from industrial wastewater. The DNR previously calculated emissions using the SIT and statewide red meat production numbers from the USDA. This method had a great deal of uncertainty as it only calculated emissions from wastewater at meat processing facilities and because it assumed a set amount of emissions from each metric ton of meat processed.

The EPA began requiring industrial wastewater facilities that emit 25,000 metric tons CO_2e or more to report to the federal greenhouse gas reporting program (GHGRP) starting with year 2011 emissions. In Iowa, this includes emissions from four food processing facilities and fifteen ethanol production facilities. The emissions reported to EPA have a higher level of accuracy than the SIT method because they are based on the unique characteristics and wastewater organic content of each facility. Last year fourteen ethanol production facilities and five food processing facilities emitted more than 25,000 metric tons CO_2e or more (EPA 2018a).

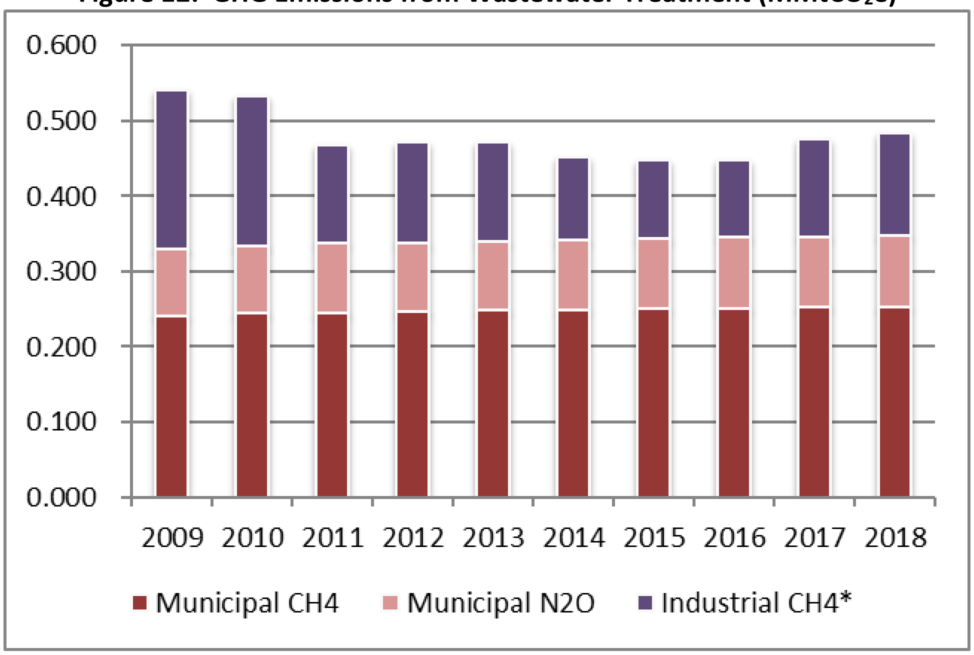
Results

Wastewater emissions account for 0.35% of total statewide GHG emissions. Total emissions from the wastewater treatment sector were 0.484 $MMtCO_2e$ in 2018, a 1.51% increase from 2017 and a 10.55% decrease from 2009 as shown in Table 25. This is due to increases in wastewater produced by industrial meat processing facilities and ethanol plants, as well as the amount of municipal wastewater produced by humans as the state's population increases. CH_4 and N_2O from municipal wastewater treatment accounted for 71.75% (0.347 $MMtCO_2e$) of total wastewater treatment GHG emissions as shown in Figure 12.

Table 25: GHG Emissions from Wastewater ($MMtCO_2e$)[22]

Sector	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Municipal CH_4	0.241	0.244	0.245	0.246	0.247	0.249	0.250	0.251	0.252	0.253
Municipal N_2O	0.089	0.090	0.093	0.092	0.093	0.093	0.094	0.094	0.094	0.095
Industrial CH_4	0.211	0.199	0.130	0.134	0.132	0.111	0.104	0.104	0.131	0.137
Total	**0.541**	**0.533**	**0.468**	**0.472**	**0.472**	**0.453**	**0.447**	**0.449**	**0.477**	**0.484**

Figure 12: GHG Emissions from Wastewater Treatment ($MMtCO_2e$)



*Does not include emissions from production of fruits and vegetables, pulp and paper.

Uncertainty[23]

Municipal Wastewater

Uncertainty is associated with both the emission factors and activity data used to calculate GHG emissions. The quantity of CH_4 emissions from wastewater treatment is based on several factors with varying degrees of uncertainty. For human sewage, there is some degree of uncertainty associated with the emission factor used to estimate the occurrence of anaerobic conditions in treatment systems based on septic tank usage data. While the Iowa-specific percentage of the population without septic systems was used to calculate emissions, the

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[22] DNR uses two decimal places throughout this report for consistency. However, in this sector three decimal places are needed show the difference in emissions from year to year.

[23] This information is largely excerpted from the *SIT Wastewater Module* (ICF 2018a).

value is from 1990. There can also be variation in the per-capita BOD production association with food consumption, food waste, and disposal characteristics for organic matter. Additionally, there is variation in these factors that can be attributed to differences in wastewater treatment facilities (ICF 2018a).

N_2O emissions are dependent on nitrogen (N) inputs into the wastewater and the characteristics of wastewater treatment methods. Estimates of U.S. population, per capita protein consumption data, and the fraction of nitrogen in protein are believed to be accurate. However, the fraction that is used to represent the ratio of non-consumption nitrogen also contributes to the overall uncertainty of these calculations, as does the emission factor for effluent, which is the default emission factor from IPCC (1997). Different disposal methods of sewage sludge, such as incineration, landfilling, or land-application as fertilizer also add complexity to the GHG calculation method (ICF 2018a).

Industrial Wastewater

GHG emissions from industrial wastewater may be underestimated because only industrial wastewater facilities that emit 25,000 $mtCO_2e$ or more are required to report to the federal greenhouse gas reporting program. Future improvements to the inventory could include identifying all of the industrial wastewater facilities that are not required to report to the federal program and developing a method to calculate their emissions.

Chapter 9 - Land Use, Land Use Change, and Forestry (LULUCF)

This chapter addresses carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O) emissions from liming of agricultural soils and fertilization of settlement soils,[24] as well as carbon sequestered by forests, urban trees, and yard trimmings and food scraps that are sent to the landfill.

Method

Forest Carbon Flux

CO_2 is taken in by plants and trees and converted to carbon in biomass during photosynthesis. "Growing forests store carbon naturally in both the wood and soil. Trees are about fifty percent carbon, and wood products from harvested trees continue to store carbon throughout their lives as well" (Flickinger 2010). CO_2 is emitted by live tree respiration, decay of dead material, fires, and biomass that is harvested and used for energy (Strait et al. 2008). The balance between the emission of carbon and the uptake of carbon is known as carbon flux (ICF 2018d).

The calculated annual forest carbon flux includes sequestration/emissions in the following forest categories:

- Carbon in live trees and saplings above ground on forest land
- Carbon in understory above ground on forest land
- Carbon in live trees and saplings below ground on forest land
- Carbon in understory below ground on forest land
- Carbon in standing dead trees on forest land
- Carbon in down dead trees on forest land
- Carbon in litter (shed vegetation decomposing above the soil surface) on forest land
- Soil organic carbon on forest land

In previous years, the DNR used data from the USDA Forest Inventory Data Online (FIDO) to calculate carbon flux. The FIDO database is no longer publically available, but the Design and Analysis Toolkit for Inventory and Monitoring (DATIM) is. It has similar functionality to FIDO, but has additional emphasis on National Forest Service data and attributes. FIDO data was used for 2009 -2015, but DATIM data was used for 2016 - 2018 (USFS 2019).

Liming of Agricultural Soils

CO_2 is emitted when acidic agricultural soils are neutralized by adding limestone or dolomite. The Iowa Limestone Producers Association (ILPA) provided the DNR with the total annual amount of limestone produced for agricultural use as reported by their members (Hall 2019). However, producers do not report the percentage of limestone that is dolomitic. The Iowa Department of Transportation (IDOT) tracks general information for active aggregate sources used for construction, including whether the material is limestone or dolomite. They do not track that information for limestone produced for agricultural purposes. The IDOT indicated that some areas of the state have 100% dolomite, some have 100% limestone, and some areas are mixed (Reyes 2011). Therefore, the DNR assumed that 50% of the material produced in Iowa for agricultural use is dolomite and 50%

[24] Settled soils such as landscaping, lawns, and golf courses (ICF 2018d).

is limestone. In 2018, EPA moved liming of agricultural soils from the SIT LULUCF module to the SIT Agriculture module. However, for consistency with previous reports, DNR included liming in this chapter.

Urea Fertilization
2017 urea emissions were calculated using the amount of urea applied annually (IDALS 2017). Because more current data is not available, 2017 was used as a proxy for 2018. In 2018, EPA has moved urea fertilization from the SIT LULUCF module to the SIT Agriculture module. However, for consistency with previous reports, DNR included urea fertilization in this chapter.

Urban Tree Flux
Carbon sequestration estimations from this sector were calculated with a DNR data set that is a mix of land cover/remote sensing data with about a one-meter resolution. The data set includes the amount of forested acres and total acres of land for 946 incorporated areas in Iowa (Hannigan 2014 and 2019).

Settlement Soils
Approximately 10% of the fertilizers applied to soils in the United States are applied to soils in settled areas such as landscaping, lawns, and golf courses (ICF 2018b). N_2O emissions from settlement soils were calculated using 10% of the total annual growing year synthetic fertilizer value from the SIT Agriculture module. For more information on how the 2018 values were derived, please see *Chapter 2-Agriculture* of this report.

Non-CO_2 Emissions from Forest Fires
CH_4 and N_2O emissions from forest fires in Iowa were not estimated because the majority of wildfires and prescribed burns in Iowa that are reported to DNR occur on grasslands (Kantak 2014). In addition, the SIT calculation method uses combustion efficiencies and emission factors that are provided for primary tropical forests, secondary tropical forests, tertiary tropical forests, boreal forest, eucalypt forest, other temperate forests, shrub lands, and savanna woodlands, which are not reflective of Iowa vegetation.

Yard Trimmings and Food Scraps Stored in Landfills
GHG estimations from this sector were refined by applying the estimated percentages of yard trimmings and food waste in municipal solid waste from the *2017 Iowa Statewide Waste Characterization Study* (MSW 2017) to the total amount of municipal solid waste sent to landfills in 2018 (DNR 2019). While the DNR was able to use more accurate Iowa values for the annual amounts of yard trimmings and food scraps stored in landfills, the DNR used the SIT default values for content of yard trimmings (e.g. % grass, % leaves, % branches), carbon content, proportion of carbon stored permanently, and half-life of degradable carbon because Iowa-specific data was not available.

Results
The majority of forest carbon is stored in above ground living trees (37%) and in the forest soil (42%) as shown in Figure 13. Overall, sources in the LULUCF sector released more carbon than they stored in 2018, releasing 0.94 $MMtCO_2e$ as shown in Table 26 and Figure 14. This is a decrease of 10.46% from 2017 and an increase of 118.78% from 2009. Emissions of CO_2 are shown above the x-axis in Figure 14 and carbon sinks are shown below the x-axis.

Figure 13: 2018 Where Forest Carbon is Stored ($MMtCO_2e$)

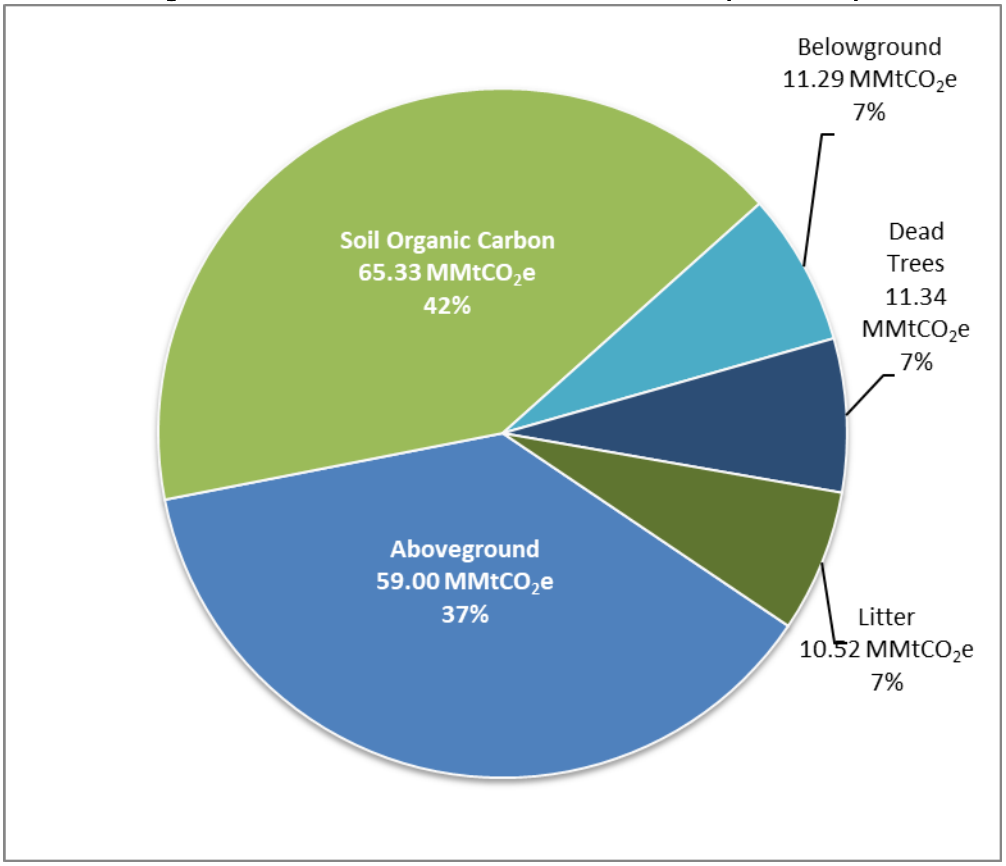
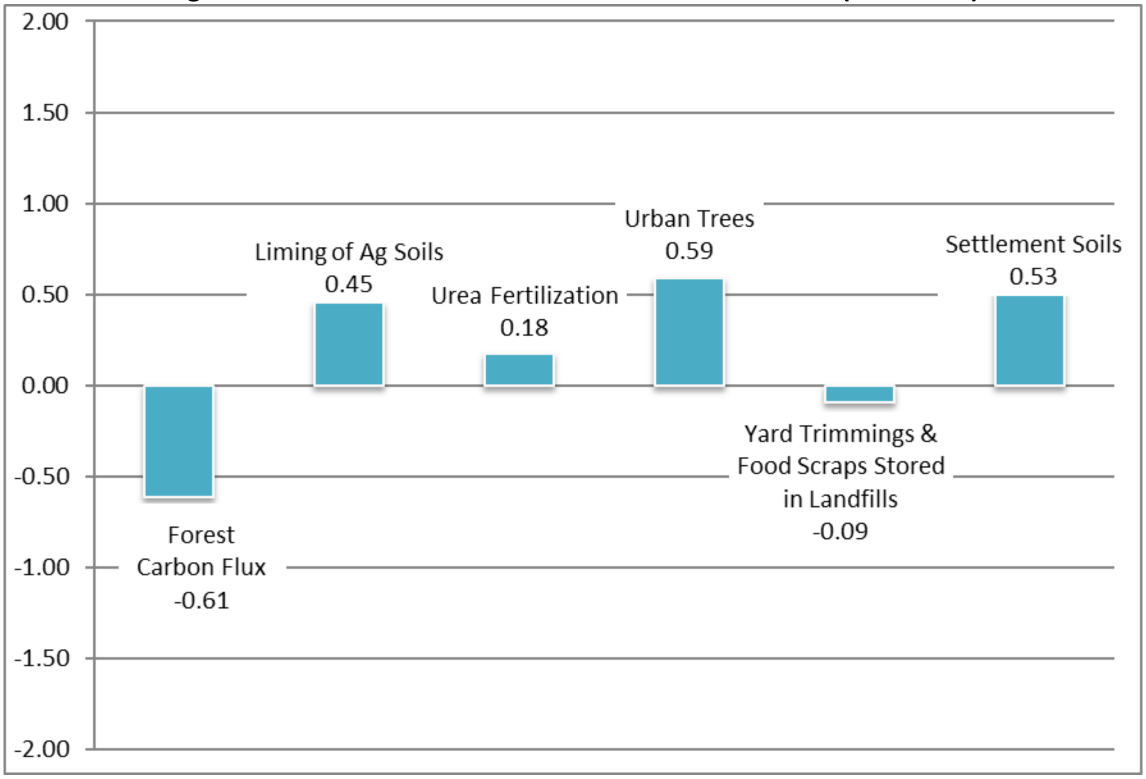


Table 26: GHG Emissions and Sinks from LULUCF ($MMtCO_2e$)[25]

Sector	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Forest Carbon Flux	-5.47	-2.68	-0.14	-0.47	-1.02	+3.04	+2.87	+1.29	-0.61	-0.61
Liming of Ag Soils	+0.27	+0.47	+0.51	+0.65	+0.47	+0.41	+0.34	+0.46	+0.45	+0.40
Urea Fertilization	+0.12	+0.11	+0.12	+0.13	+0.11	+0.15	+0.15	+0.19	+0.18	+0.18
Urban Trees	-0.26	-0.28	-0.28	-0.28	-0.74	-0.74	-0.74	-0.74	+0.59	+0.59
Yard Trimmings & Food Scraps Stored in Landfills	-0.10	-0.10	-0.13	-0.12	-0.11	-0.12	-0.12	-0.12	-0.09	-0.10
N_2O from Settlement Soils	+0.44	+0.48	+0.57	+0.57	+0.57	+0.49	+0.49	+0.51	+0.53	+0.48
Total	**-5.00**	**-2.01**	**+0.67**	**+0.48**	**-0.71**	**+3.27**	**+2.99**	**+1.59**	**+1.05**	**+0.94**

[25] Carbon emitted from the LULUCF sector is shown as a positive number. Carbon stored by the LULUCF sector is shown as a negative number.

Figure 14: 2018 GHG Emissions and Sinks from LULUCF (MMtCO$_2$e)



Uncertainty

Uncertainty in the LULUCF sector is due to the lack of current Iowa-specific data and emission factors used to calculate emissions and/or sinks from urban trees and settlement soils. Emissions from categories such as urea fertilization, liming of agricultural soils, and yard trimmings and food scraps stored in landfills are more certain because Iowa-specific activity data was used. However, uncertainty was also introduced by:

- Using surrogate urea data for 2017,
- Using growing year synthetic fertilizer data for settlement soils instead of calendar year data,
- Assuming the ratio of limestone to dolomite in Iowa is 50%, and
- Using SIT default values for content of yard trimmings (e.g. % grass, % leaves, and % branches), carbon content, proportion of carbon stored permanently, and half-life of degradable carbon.

In addition, due to the high uncertainty in soil carbon flux from tillage practices, it was not included in the DNR's calculations. Refer to *Chapter 2 – Agriculture* for more information.

Chapter 10 – Electricity Consumption

This chapter includes indirect emissions from electricity consumed at the point of use (e.g. residential electric hot water heaters, televisions, appliances, etc.) and does not include direct emissions generated at the electric power generating station (*see Chapter 3 – Fossil Fuel Combustion*).

Electricity consumed by Iowans may not be generated in Iowa. Because of this, emissions from electricity consumption do not match emissions from electricity generation (ICF 2018b). Therefore, GHG emissions from electricity consumption are included in this inventory as an informational item only and are not included in the total statewide GHG emissions to avoid any possible double counting. However, trends in electricity consumption are valuable because they are indicators of consumer behavior and trends in energy efficiency.

Method

GHG emissions were calculated using the Electricity Consumption SIT module (ICF 2018a).

Residential, Commercial, and Industrial

2018 emissions were projected by applying the forecasted percent change in energy consumption for each sector for the West North Central Region in the EIA's *Annual Energy Outlook (AEO) 2019 with Projections to 2050* (EIA 2019a) to Iowa's 2017 electricity consumption data from EIA (EIA 2019b).

Transportation

The first time that DNR calculated indirect emissions from electricity consumption in the transportation sector was for 2015. According to the Iowa Legislative Services Agency (LSA 2019), 3,241 electric vehicles were registered in Iowa as of May 1, 2019. This is an increase of 170.0% from 2016, but is 0.07% of the total number of vehicles, 4.51 million, registered in the state in 2018 (IDOT 2019). Emissions were calculated assuming that each electric vehicle consumes 4,250 kWh of electricity per year (IEDA 2016). This does not include emissions from electric propulsion, other electric batteries, or non-highway electric vehicles such as golf carts.

Adjustments

2017 emissions have been recalculated since the DNR's 2017 GHG Inventory Report was published in December 2018. The DNR previously forecasted 2017 emissions due to a lack of Iowa-specific energy consumption data. However, the 2017 energy data was released by EIA in June 2019 (EIA 2019b), so the DNR used the data to recalculate 2017 emissions as shown in Table 27 and Table 28.

Table 27: Updated 2017 Activity Data

Category	2017 Value Published Dec. 2018	2017 Updated Value
Electricity Consumption (kWh)		
Residential	14,062,993,200	13,722,000,000
Commercial	12,260,272,500	12,135,000,000
Industrial	22,262,050,800	23,065,000,000
Total	**48,585,316,500**	**48,922,000,000**

Table 28: Recalculated Electricity Emissions ($MMtCO_2e$)

Category	2017 Value Published Dec. 2018	2017 Updated Value
Residential	6.70	6.54
Commercial	5.84	5.79
Industrial	10.61	11.00
Total	**23.16**	**23.32**

Results

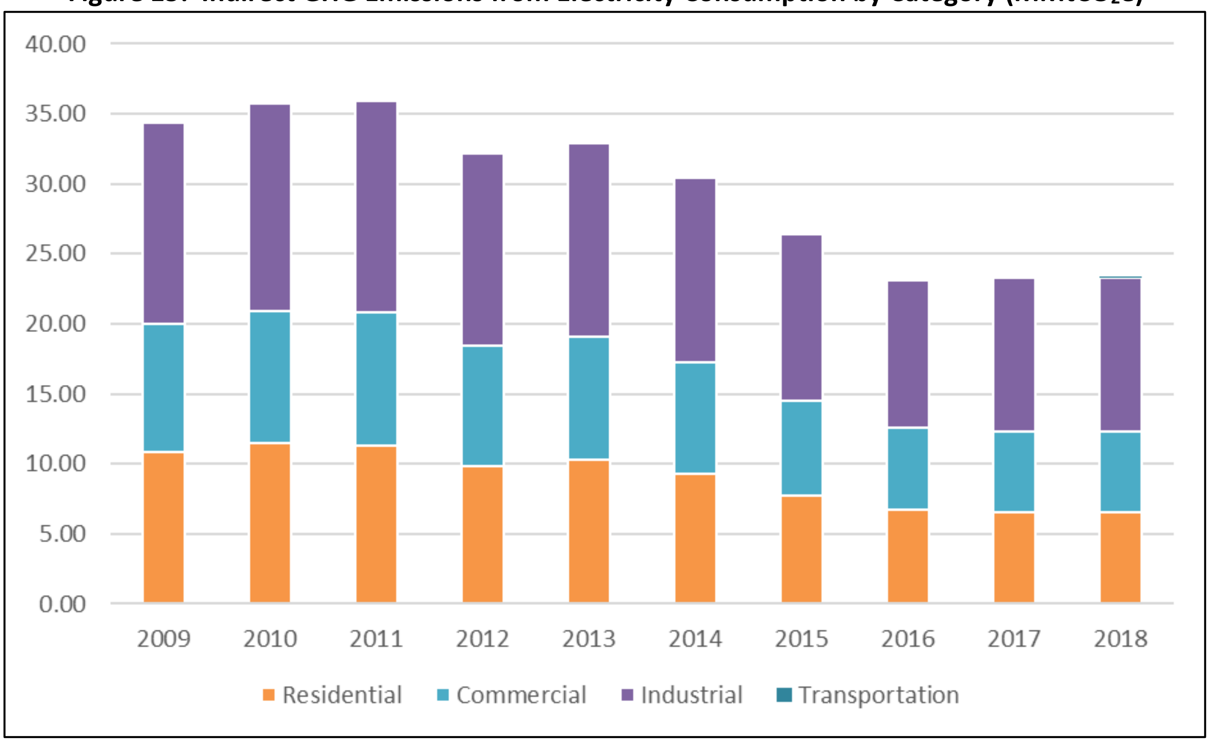
Indirect GHG emissions from electricity consumption were 23.34 $MMtCO_2e$ in 2018, increasing 0.07% since 2017, due to projected increases in electricity consumption in all four categories (EIA 2019a) as shown in Table 29 and Figure 15. Industrial users consumed the largest percentage of electricity, 47.11%, as shown in Figure 16.

Table 29: GHG Emissions from Electricity Consumption ($MMtCO_2e$)[26]

Category	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Residential	10.80	11.45	11.27	9.85	10.30	9.29	7.72	6.72	6.54	6.55
Commercial	9.21	9.46	9.51	8.60	8.77	7.64	6.76	5.86	5.79	5.79
Industrial	14.33	14.84	15.14	13.74	13.83	13.16	11.92	10.51	11.00	11.00
Transportation	*not calculated**						0.00	0.00	0.00	0.01
Total	**34.35**	**35.76**	**35.92**	**32.19**	**32.90**	**30.39**	**26.41**	**23.09**	**23.32**	**23.34**

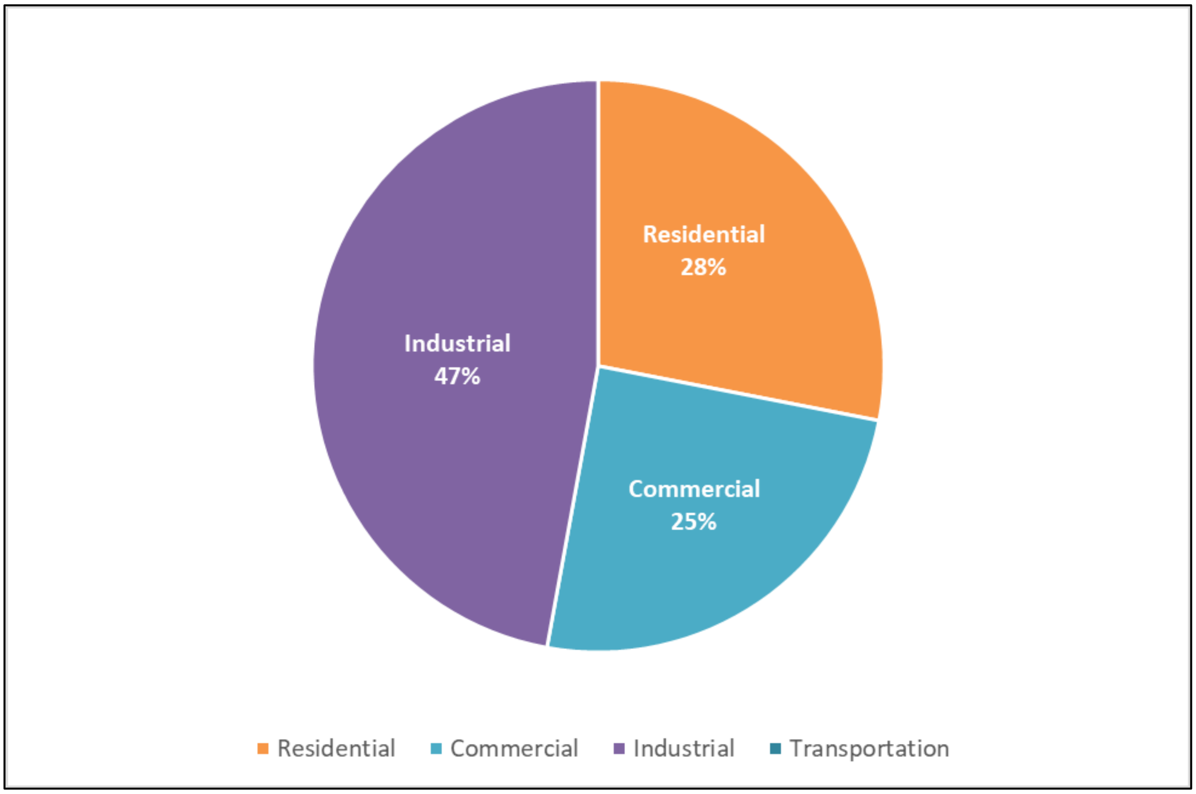
* 2015 was the first time that DNR calculated indirect emissions from electricity consumption.

Figure 15: Indirect GHG Emissions from Electricity Consumption by Category ($MMtCO_2e$)



[26] Totals may not equal the sum of subtotals shown in this table due to independent rounding.

Figure 16: Electricity Consumption by Category[27]



[27] Emissions from transportation round to 0%.

Forecasting

Iowa Code 455B.104 requires that the DNR forecast trends in GHG emissions.

Method

The DNR projected emissions out to 2030 using the SIT Projection Tool (ICF 2019a and 2019b). The Projection Tool predicts that Iowa's population decreases every year from 2012 – 2030. This is contrary to the most recent population projections available from the U.S. Census. Consequently, the DNR replaced the Projection Tool default populations with the actual Iowa population for 2007 -2018 (U.S. Census 2019) and the 2020, 2025, and 2030 projections from Woods & Poole Economics (Woods & Poole, 2009). The data points for the intervening years were calculated using linear interpolation.

The Projection Tool forecasts emissions from industrial processes, agriculture, and waste based on historical emissions from 1990 – 2017, using a combination of data sources and national projections for activity data. The Projection Tool would ideally include data through 2018 to be consistent with the DNR's 2018 calculated GHG inventory, but this discrepancy is unavoidable. It would be preferable to forecast emissions using the DNR's 2018 calculated GHG inventory as the baseline, but it is not reasonable to fully update the data in the SIT Projection Tool to eliminate all such inconsistencies.

Results

The DNR's calculated 2018 GHG inventory and projected emissions from the SIT Projection Tool for "2018," 2020, 2025, and 2030 for each category are shown in Table 30 (intervening year forecasts are available from the DNR upon request). The 2018 "forecast" was produced to help gauge the reasonableness of the projections. Only the Agriculture, RCI Fossil Fuel Use, and Natural Gas T & D sectors yielded a 2018 forecast within 1 $MMtCO_2e$ of its calculated value.

Table 30: Projected Gross GHG Emissions 2018 – 2030 ($MMtCO_2e$)

	Calculated	Projected			
Sector	**2018**	**2018**	**2020**	**2025**	**2030**
Agriculture	41.63	41.71	43.98	49.67	55.37
Power Plants	30.87	25.21	23.65	25.55	25.73
RCI Fossil Fuel Use	32.06	31.70	30.49	31.71	32.10
Industrial Processes	7.40	4.07	4.56	5.54	6.43
Natural Gas T & D	1.41	1.45	1.51	1.49	1.59
Transportation	20.40	22.75	22.65	21.22	20.02
Waste	2.78	4.06	4.13	4.34	4.54
Total	**137.49**	**130.94**	**130.96**	**139.62**	**145.79**

Uncertainty

As with many forecasts, numerous factors affect the significant level of uncertainty associated with emissions projections. These factors include the economy, weather, current and future environmental regulations, energy efficiency and conservation practices, driving practices, use of renewable fuels, and other variables. Although the SIT Projection Tool provides a useful first look at projected future emissions, it has several specific areas of uncertainty:

1. Agricultural emissions are highly dependent on the weather and crop and livestock prices, which are not addressed by the Projection Tool.

2. Emissions from electric power plants and RCI fuel combustion are also highly dependent on weather and the number of heating and cooling days per year.
3. Emissions from electric power plants also may fluctuate due to differences in how electricity generation is dispatched by MISO, electricity demand by customers, and other market forces.
4. In sectors where the Projection Tool predicts future emissions based on historical emissions (industrial processes, agriculture, and waste), it only uses emissions from 1990 – 2017 and does not consider 2018 data.

References

Unless otherwise noted, all emails referenced were sent to Marnie Stein, Air Quality Bureau, Iowa Department of Natural Resources in Des Moines, Iowa.

General Method

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Appendix A – Iowa GHG Emissions 2009 – 2018 by Sector[28]

Emissions (MMtCO$_2$e)	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Agriculture	36.48	36.38	37.91	36.78	35.77	36.75	39.00	39.49	**41.71**	41.63
Enteric Fermentation	8.02	8.39	8.41	8.40	8.38	8.19	8.36	8.43	**8.40**	8.45
Manure Management	9.59	8.83	9.53	10.86	10.85	10.42	11.07	10.96	**11.75**	11.70
Agricultural Soil Management	18.87	19.16	19.98	17.53	16.55	18.14	19.58	20.09	**21.56**	21.48
Fossil Fuel Combustion	68.44	73.56	70.42	65.72	65.88	66.26	61.00	54.78	**58.67**	62.93
Electric Generating Facilities	37.71	42.33	38.98	35.76	33.06	33.44	29.46	25.33	26.62	30.87
Residential, Commercial, Industrial	30.73	31.23	31.44	29.96	32.82	32.82	31.54	29.45	**32.05**	32.06
Industrial Processes	4.21	4.79	4.50	5.18	**5.07**	**5.12**	**5.09**	**5.34**	**7.10**	7.40
Ammonia & Urea Production	0.60	0.84	0.75	0.85	0.88	0.86	0.81	0.92	2.60	3.26
Cement Manufacture	0.84	0.72	0.79	1.27	1.41	1.38	1.50	1.58	1.66	1.30
Electric Power Transmission and Distribution Systems	0.07	0.07	0.07	0.06	**0.06**	**0.06**	**0.05**	**0.06**	**0.06**	0.06
Iron and Steel Production	0.09	0.23	0.20	0.23	0.19	0.18	0.16	0.19	0.20	0.19
Lime Manufacture	0.13	0.18	0.18	0.18	0.16	0.17	0.13	0.15	0.18	0.16
Limestone and Dolomite Use	0.29	0.39	0.16	0.15	0.18	0.21	0.21	0.21	0.21	0.21
Nitric Acid Production	0.87	0.95	0.90	0.96	0.80	0.82	0.74	0.75	0.70	0.73
ODS Substitutes	1.30	1.39	1.43	1.47	**1.39**	**1.42**	**1.45**	**1.47**	**1.47**	1.47
Soda Ash Consumption	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
LULUCF[29]	-5.00	-2.01	0.67	0.48	-0.71	3.27	2.99	**1.59**	**1.05**	0.94
Forest Carbon Flux	-5.47	-2.68	-0.14	-0.47	-1.02	3.04	2.87	**1.29**	**-0.61**	-0.61
Liming of Agricultural Soils	0.27	0.47	0.51	0.65	0.47	0.41	0.34	0.46	0.45	0.40
Urea Fertilization	0.12	0.11	0.12	0.13	0.11	0.15	0.15	0.19	0.18	0.18
Urban Trees	-0.26	-0.28	-0.28	-0.28	-0.74	-0.74	-0.74	-0.74	**0.59**	0.59
Yard Trimmings and Food Scraps Stored in Landfills	-0.10	-0.10	-0.13	-0.12	-0.11	-0.12	-0.12	-0.12	**-0.09**	-0.10
Fertilization of Settlement Soils	0.44	0.48	0.57	0.57	0.57	0.52	0.49	0.51	0.53	0.48

[28] Totals may not equal the exact sum of subtotals in this table due to independent rounding. Values that have been adjusted since the previous inventory are in bold and are described in detail in this document.
[29] Carbon emitted from the LULUCF sector is shown as a positive number. Carbon stored by the LULUCF sector is shown as a negative number.

Emissions (MMtCO_2e)	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**
Natural Gas Transmission & Distribution	1.40	1.39	1.40	1.40	1.40	1.40	1.40	1.41	1.27	1.41
Transmission	0.79	0.79	0.79	0.79	0.79	0.79	0.79	0.79	0.79	0.79
Distribution	0.61	0.60	0.61	0.62	0.61	0.62	0.61	0.62	0.48	0.62
Transportation	19.40	19.41	19.58	19.59	19.46	19.55	20.02	20.12	**20.42**	20.40
Waste	3.06	2.01	1.94	2.15	1.96	1.93	2.14	2.16	2.78	2.78
Solid Waste	2.52	1.47	1.47	1.68	1.49	1.48	1.69	1.71	2.30	2.30
Wastewater	0.54	0.53	0.47	0.47	0.47	0.45	0.45	0.45	0.48	0.48
Gross Emissions	132.98	137.54	136.40	131.30	**129.55**	**134.29**	**131.64**	**124.89**	**133.00**	137.49
Sinks	-5.00	-2.01	0	0	-0.71	0	0	0	0	0
Net Emissions	127.99	135.53	136.40	131.30	**128.83**	**134.29**	**131.64**	**124.89**	**133.00**	137.49
% Change from Previous Year (Gross)	-4.43%	+3.43%	+0.64%	-3.74%	**-1.34%**	**+3.66%**	**-1.97%**	**-5.13%**	**+6.49%**	+3.38%
% Change from 2009 (Gross)		+3.43%	+2.57%	-1.26%	-2.58%	+0.98%	-1.01%	-6.09%	+0.01%	+3.39%

Appendix B – Iowa GHG Emissions 2009 – 2018 by Pollutant[30]

Emissions ($MMtCO_2e$)	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Gross CO_2	89.08	94.54	91.43	87.32	87.53	90.76	85.81	**78.60**	**84.00**	88.37
Net CO_2	83.65	92.05	91.43	87.22	86.24	90.76	85.81	**78.60**	**84.00**	88.37
Stationary Fossil Fuel Combustion	68.09	73.09	69.96	65.30	65.47	65.85	60.64	54.51	56.12	62.58
Transportation	19.00	19.04	19.27	19.31	19.21	19.32	19.81	19.93	20.17	20.18
Industrial Processes	1.97	2.38	2.09	2.69	2.83	2.83	2.84	3.07	4.87	5.14
Solid Waste	0.02	0.02	0.02	0.02	0.02	0.02	0.01	0.01	0.01	0.01
LULUCF[31]	-5.43	-2.49	0.09	-0.09	-1.29	2.75	2.50	**1.08**	**0.52**	0.46
CH_4	21.12	20.17	20.21	21.72	21.50	20.86	21.88	21.80	**23.08**	23.19
Stationary Fossil Fuel Combustion	0.11	0.19	0.19	0.17	0.17	0.17	0.14	0.09	**0.13**	0.14
Transportation	0.04	0.04	0.04	0.04	0.04	0.04	0.03	0.03	**0.03**	0.03
Natural Gas and Oil Transmission and Distribution	1.40	1.39	1.40	1.40	1.40	1.40	1.40	1.41	1.27	1.41
Enteric Fermentation	8.02	8.39	8.41	8.40	8.38	8.19	8.36	8.43	**8.40**	8.45
Manure Management	8.61	8.26	8.36	9.67	9.67	9.24	9.91	9.79	**10.58**	10.47
Solid Waste	2.50	1.45	1.45	1.66	1.48	1.46	1.68	1.70	2.29	2.29
Wastewater	0.45	0.44	0.38	0.38	0.38	0.36	0.35	0.36	0.38	0.39
N_2O	21.85	21.85	23.25	20.83	19.65	21.20	22.46	22.98	**24.39**	24.40
Stationary Fossil Fuel Combustion	0.24	0.28	0.27	0.25	0.24	0.24	0.21	0.19	**0.18**	0.20
Transportation	0.36	0.33	0.27	0.24	0.21	0.19	0.18	0.16	**0.14**	0.19
Industrial Processes	0.87	0.95	0.90	0.96	0.80	0.82	0.74	0.75	0.70	0.73
Manure Management	0.98	0.57	1.17	1.19	1.18	1.18	1.16	1.17	**1.17**	1.23
Agricultural Soil Management	18.87	19.16	19.98	17.53	16.55	18.14	19.58	20.09	**21.56**	21.48
N_2O from Settlement Soils	0.44	0.48	0.57	0.57	0.57	0.52	0.49	0.51	0.53	0.48
Solid Waste	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Wastewater	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09
HFC, PFC, and SF_6	1.37	1.46	1.50	1.53	1.44	1.47	1.50	1.53	1.53	1.53
Industrial Processes	1.37	1.46	1.50	1.53	1.44	1.47	1.50	1.53	1.53	1.53
Gross Emissions	133.42	138.02	136.40	131.40	**130.12**	**134.29**	**131.64**	**124.89**	**133.00**	137.49
Sinks	-5.43	-2.49		-0.09	-1.29					
Net Emissions (Sources and Sinks)	127.99	135.53	136.40	131.30	**128.83**	**134.29**	**131.64**	**124.89**	**133.00**	137.49

[30] Totals may not equal the exact sum of subtotals in this table due to independent rounding. Values that have been adjusted since the previous inventory are in bold and are described in detail in this document.

[31] Carbon emitted from the LULUCF sector is shown as a positive number. Carbon stored by the LULUCF sector is shown as a negative number.